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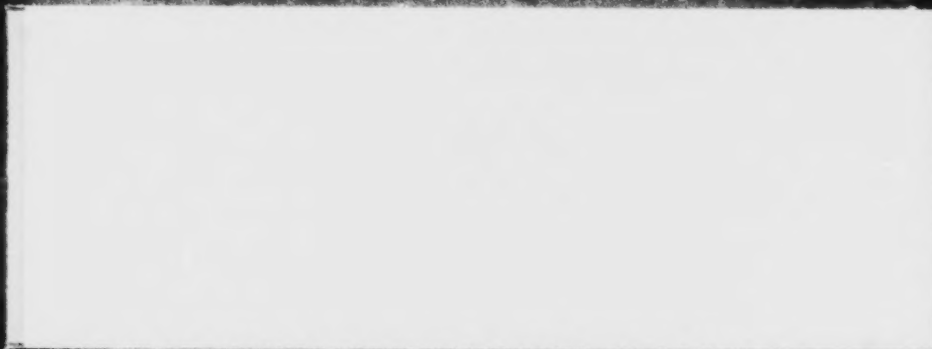
CANMET

Canada Centre
for Mineral
and Energy
Technology

Centre canadien
de la technologie
des minéraux
et de l'énergie

POTASH MINING PROJECT

PROJET D'EXPLOITATION DE LA POTASSE



**PROGRAMME DE RECHERCHE SUR LES MINÉRAUX
LABORATOIRES DE RECHERCHE MINIÈRE**

**MINERALS RESEARCH PROGRAM
MINING RESEARCH LABORATORIES**

A FIELD TEST PROGRAM TO EVALUATE
THE USE OF WASTE SALT BACKFILL
IN SASKATCHEWAN POTASH MINES
- FINAL REPORT -

Participating Companies

Central Canada Potash
Centre de Recherche Noranda
Potash Corporation of Saskatchewan Mining Limited

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EXECUTIVE SUMMARY

Central Canada Potash (CCP) jointly with the Centre de Recherche Noranda (CRN) and the Potash Corporation of Saskatchewan Mining Limited (PCS-Mining) submitted a proposal dated 23 December, 1984, in response to the Department of Supply and Services Canada (DSS) request for proposal RFP 26SQ.23440-3-9206, dated 22 November, 1983, titled "Collection of Field Data Around Excavations in Potash or Salt Areas to Evaluate Excavation Performance or Concepts for New Mining Layouts".

The joint proposal of CCP, CRN, and PCS-Mining was accepted by DSS and contract No. OSQ83-00323, titled "A Field Test Program to Evaluate The Use of Waste Salt Backfill in Saskatchewan Potash Mines" was issued to CCP by DSS on 20 March, 1984.

This Final Report is submitted in compliance with the terms of the contract.

The objectives of the project are: to study and analyse the behaviour of salt backfill on a production scale basis; to study and analyse the effectiveness of grouting and backfill techniques as means

to control brine inflow; study the in-situ long term behaviour of the Dawson Bay during mine closure; to develop a data base that would supply information on ground stability, ground support, salt backfill, grouting techniques, ground behaviour and subsidence; to study and analyse the creep and failure characteristics of potash and salt.

The project involved laboratory and field research work. Diamond drilling, grouting and field instrumentation formed the core of the field work which was designed in the following sequence: rehabilitate the accessways to the panels; drill a series of holes in the inflow areas and study the brine flow characteristics; grout off the Dawson Bay Formation to control and eliminate, if possible, the inflow; instrument the rock formations and backfill zones; backfill the test areas to reduce the room closure rate and ground subsidence, and to control the deformation behaviour of the Dawson Bay; continue to observe the area and collect data for further years along with subsidence records. The laboratory work included testing of the backfill and mine rock formations.

The following summarizes the achievements realized in the project:

Rehabilitation of Access: Access ways to the two panels used for the tests were rehabilitated. A total of 2900 metres (9500 feet) of access to Panel 109 and 2200 metres (7200 feet) of access to Panel 209 were rehabilitated. Access into the panels was developed in preparation for the drilling,

grouting, instrumentation and backfill programs. Approximately 670 metres (2200 feet) of access was developed in Panel 209, and approximately 457 metres (1500 feet) developed in Panel 109. Five diamond drilling stations were prepared in Panel 209 and four in Panel 109.

Exploratory Drilling: An exploratory drilling program was established to investigate the geology and the source of brine entering Panels 209 and 109. A monitoring program of chemical composition, specific gravity, pH level, temperature, brine formation pressure and brine flow was continued. The Dawson Bay Formation had been established as the primary brine source and the variation of brine flow with time was determined.

Grouting: A drilling and grouting program was prepared to control and ultimately seal the brine inflow in Panels 109 and 209, in preparation for the backfilling operation. Thirteen exploratory grout holes were drilled in Panel 209 and the overlying Dawson Bay Formation grouted to deflect brine inflow. The grouting operation in Panel 209 resulted in a 89% reduction of the brine inflow volume. Four holes were initially drilled and tested in Panel 109 and flow and dye tests were performed. A drill hole layout consisting of six additional holes was designed and cement grout will be used to form a curtain of grout around the inflow.

Instrumentation: Selected sections in the panels were instrumented to evaluate the load/deformation characteristics of the surrounding strata. The instrumentation program involved the gathering of information from previous studies undertaken in the area, including geophysical evaluations, geologic maps and exploration drill logs. A series of temporary and permanent instrumentation stations were developed in Panel 209. The temporary stations consisted of eleven room closure pin stations and two deep pin stations. Two full instrumentation stations, one pillar instrumentation station, four secondary instrumentation stations and two borehole instrumentation stations form the data gathering system established for Panel 209. The selected instruments for Panel 209 included two convergence meters for the rooms, four earth pressure cells and six piezometers for the backfill, five extensometers and three borehole pressure cells for the host salt and potash formations, and two stressmeters and four strain gauges for the Dawson Bay Formation. Two room closure pin stations and one deep pin station were installed in Panel 109. One full instrumentation station, one secondary instrumentation station and two borehole instrumentation stations form the data gathering system established for Panel 109. The selected instruments for Panel 109 included one convergence meter, two earth pressure cells, one piezometer, two borehole extensometers, two stressmeters and two strain gauges.

Data Collection: All the instruments installed in Panel 209 were connected to a data acquisition system, specially designed to receive and store the transmitted instrument data. The data acquisition system consists of a data logging system and an Otrona Attache host computer. Approximately 4600 metres (15100 feet) of cable was used for the connections between the instruments and the microprocessor, and a total of 84 wires were fed to the data acquisition system. All the instruments installed in Panel 109 will be connected to a manual reading station, specially designed to receive the transmitted instrument data. The manual reading station consists of a 12 channel switch box an excitation unit, a voltmeter and a vibrating wire readout box. Approximately 1050 metres (3450 feet) of cable will be used for the connections between the instruments and the reading station, and a total of 30 wires will be fed to the data collection system. An invaluable data base is being developed representing the most reliable and realistic information on the long term behaviour of the rock formations typical of the Saskatchewan potash mines.

Backfilling: A series of backfilling techniques were analysed and pneumatic stowing was selected as the best alternative. Salt muck for backfilling will be supplied by the AM50 and scoop trams will be used to feed the stowing system with the waste salt. Approximately 20000 tonnes (22000 tons) of waste salt will be required to backfill Panel 209 and approximately 10000 tonnes (11000 tons) for Panel 109.

Laboratory Testing: An extensive program of laboratory tests was designed to investigate the basic physical characteristics of the mine rock formations and salt backfill. The Dawson Bay, First Red Bed and Second Red Bed Formations were core sampled and laboratory tested. Brazilian tests and uniaxial and triaxial compression tests were conducted. A total of 340 tests were performed at Queen's University. The backfill material was sampled and a laboratory testing program initiated. The tests investigate some of the relevant variables involved with the backfilling operation: material composition, size analysis, density, porosity, permeability, moisture content, strength, etc.

The following summarizes the tasks yet to be completed: additional instrumentation of the Dawson Bay; grouting of the Dawson Bay in one panel; additional instrumentation in both panels; backfilling of both panels with crushed salt waste; long term evaluation of the project data.

1 INTRODUCTION

Central Canada Potash (CCP) jointly with the Centre de Recherche Noranda (CRN) and the Potash Corporation of Saskatchewan Mining Limited (PCS-Mining) submitted a proposal dated 23 December, 1984, in response to the Department of Supply and Services Canada (DSS) request for proposal RFP 26SQ.23440-3-9206, dated 22 November, 1983, titled "Collection of Field Data Around Excavations in Potash or Salt Areas to Evaluate Excavation Performance or Concepts for New Mining Layouts".

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This Final Report is submitted in compliance with the terms of the contract.

1.1 BACKGROUND AND PERSPECTIVE

Potash deposits, limited to a few producing countries in the world, are the main source of potassium compounds consumed in industry and are of particular importance to the agricultural industry worldwide, which demands a soluble source of potassium in large quantities as fertilizer.

Potash was discovered in Saskatchewan in the early 1940's and brought to production in the 1960's. The Saskatchewan potash deposits account for some 40% of world reserves and Canada is the leading producer of potash in the western world. These deposits are renowned for their richness, thickness, flatness, continuity and extent. These factors and the presence of a protective, relatively competent salt back have permitted a high degree of mechanization. The advantages of size, continuity and grade are however offset to some extent by the depth of the deposits, the presence of water bearing formations in the overburden and the remoteness of markets.

In the past two decades substantial research has been done to develop the technology needed to cope with the unique conditions in Saskatchewan mines. European shaft construction techniques were adopted to cope with the problems associated with maintaining stable shafts in the weak, water-bearing overburden and continuous mechanized mining systems were developed. Mine ventilation, and the stability of

mine openings were made more manageable by the introduction of the mechanized mining methods.

Rock mechanics research programs were developed early to assure general mine safety and to assess the problems associated with mining potash at depth. Early research was therefore focused on the identification of criteria for determining and establishing the following factors: the stability of pillars and the minimum pillar size; the stability of the immediate roof and floor; the influence of clay bands on roof stability; the association between opening width and opening stability; controlled closure of excavations; the best extraction ratio possible; shaft stability; the safest mining layouts; the control of subsidence of overlying rocks and ground surface as a result of mining.

Past research was notably characterized by experimental mining trials, measurements of ground movement within the mine, rock mechanics instrumentation, the use of geophysical techniques, laboratory testing of potash and salt samples, theoretical work on the stability of openings in salt, and the development of structural models. The practical result of this research was the development of multiple entry systems incorporating yielding pillars for access ways and the chevron type layouts for production panels. With the exception of one mine, these and the panel and pillar mine layout are used in one form or another throughout the industry. These developments proved the viability of extracting potash

from between 950 m and 1100 meters depth using a high degree of mechanization.

At Central Canada Potash, the use of stress relief and yield pillars in the design of the mining layouts has resulted in overall stable underground excavations and safe mining practices. There are two types of production rooms: Chevron and hybrid, which result in a planned block average extraction ratio of 35%. Mining activity has resulted in minor brine ingresses in two areas, and additional operating costs have been incurred over the years. CCP has established an intense research program in those two areas.

The proposed program included the development and use of grouting and backfilling techniques in conjunction with instrumentation of the areas to develop a data base and expertise to suggest methods of increasing the efficiency of mining. In the long term the project may provide means for developing alternative safe mine layouts which would improve the exploitation of potash resources.

1.2 PROJECT JUSTIFICATION

CCP's operations have been characterized by overall low costs and safe mining practices. However, mining activities have triggered occasional brine ingresses, resulting in high repair and maintenance costs.

Grouting and salt backfilling are viable techniques to control brine inflows in underground excavations in potash mines. Detailed instrumentation of the backfilled test areas provides information on the long term behaviour and effectiveness of the grout/backfill system, allowing for rational decisions on the complete abandonment of these mined out areas, thus resulting in considerable operational cost savings.

The use and study of grouting/backfill techniques could ultimately offer the following series of benefits to the Canadian potash mining industry: provide an economic and available support mechanism that could limit creep deformation, control subsidence and increase resource recovery; provide technology to control and seal off some types of brine inflows; underground salt backfilling would substantially reduce the environmental hazards related to the accumulation of waste salt on surface; it could increase the extraction ratio and give longer reserve life; it would provide means of potential cost savings as a result of reduction in material handling.

The expertise used at CCP to safely drill the surrounding formations has eliminated the risk of uncontrollable influxes of brine and simplifies the measurements of ground movement at depths beyond the influence of individual mining openings, which is critical to the rational development of realistic design models.

This data, collected in the field, provides invaluable information for the Saskatchewan mining industry.

1.3 RESEARCH ISSUES AND OBJECTIVES

The objectives of the project are:

1 - study and analyse the behaviour of salt backfill on a production scale basis.

2 - study and analyse the effectiveness of grouting and backfill techniques as a means to control brine inflow.

3 - develop a data base that would supply information on ground stability, ground support, salt backfill, grouting techniques, ground behaviour and subsidence.

4 - study and analyse the creep and failure characteristics of potash and salt.

The proposed program offers the opportunity to study the Dawson Bay Formation, which has never been studied in detail from underground. Field instrumentation and laboratory tests will serve to determine the response of the formation to stress changes due to mining and the in-situ long term behaviour of the formation during mine closure.

This project covers, directly or indirectly, the following needs in potash mining: field studies consisting of in-situ measurements of ground stress and strata movement; field studies consisting of in-situ measurements of movement and deformation within the mine workings; establishment of a data base to reflect the stability of mine openings; establishment of feasible and reliable ground monitoring and data collection techniques, with the use of computers; establishment of safe grouting procedures and the study of its long term effectiveness; investigate the mechanism of ground response to mining; investigate the mechanism of load transfer with time and load concentrations due to mining; investigate the effect of salt backfill on closure and stress redistribution; investigate the performance of mine pillars as regional support; laboratory studies to determine the support characteristics of salt backfill; laboratory studies to determine the elastic characteristics of the Dawson Bay Formation.

1.4 WORK SCOPE OF THE PROJECT

The work scope of the project is:

1 - identify the effects of salt backfill in terms of mine stability, subsidence and optimization of mining extraction.

2 - identify the effects of grouting procedures to arrest brine inflow.

3 - establish excavation behaviour mechanisms through field instrumentation and modelling procedures.

4 - establish the load-deformation characteristics of the Dawson Bay Formation through field instrumentation and laboratory testing.

5 - identify further research required to address issues concerning mine stability and ground control.

1.5 METHODOLOGY USED

Representatives of the participating companies set up a tripartite committee to manage and oversee the project to its completion. A graduate trained engineer was hired and a technical team was organized to conduct the field research program. This team was responsible for the operational and rock mechanics aspects of the field research program. The project team held regular meetings during the research program to establish, review, update and approve the overall terms, guide lines, operating procedures, methodology, objectives, research issues, work scope, development and progress of work. The coordination, organized effort and willing contribution of the project team were crucial for the success of the program. The physical resources of the three groups were used on a regular basis and a number of specialty contractors and research groups were also contacted as needed.

The following summarizes the methodology used in the field research program:

1 - access ways to the two panels used for the tests were rehabilitated, the two panels were reopened, a series of exploratory holes drilled, and the overlying Dawson Bay Formation grouted to deflect brine inflow.

2 - selected sections in the panels were instrumented to evaluate the load/deformation characteristics of the surrounding strata.

3 - the instrumentation was connected to a data acquisition system, installed underground.

4 - the Dawson Bay Formation was instrumented to evaluate its load/deformation characteristics during mine room closure.

5 - initial data was collected and analysed.

6 - the overlying formations were core sampled and laboratory tested.

7 - the backfill material was sampled and a laboratory testing program initiated.

The Chief Mine Engineer from CCP was responsible for all operational aspects of the field program, and the hired engineer, under the supervision of the tripartite committee, was responsible for the technical designs, instrumentation installation and maintenance, laboratory testing, documentation and data analysis.

The field research program is successfully progressing at the moment and the tests, yet to be completed, include: additional instru-

mentation of the Dawson Bay; grouting of the overlying Dawson Bay Formation in one panel; additional instrumentation in both panels; back-filling of both panels with crushed salt waste; evaluation of the project data, in the long term, with respect to brine inflow containment, ground support performance, potential for increased extraction ratio.

The technical aspects of the investigations are presented and discussed in detail in this report.

1.6 LIMITATIONS OF THE PROJECT

A series of physical and operational limitations have affected the completion of the objectives of this project within the proposed time frame.

Most of the limitations were unavoidable and have affected the completion of the project to date. Unexpected delays have occurred for the following reasons: equipment breakdown, delaying the progress of rehabilitating access ways and of drilling the strata for grouting and instrumentation purposes; poor or deteriorating ground conditions halted work several times due to the need to rehabilitate access or install ground support; occurrence of minor gas ingresses; the need to improve venti-

lation; increased haulage distances as ground closure has extensively reduced local muck storage capability; mine shutdowns.

At the time of writing, the project has progressed satisfactorily. Completion is expected within the year. It should also be noted that field studies in the area of ground stability in 'soft rock' are of a long term nature due to the time dependent nature of most deformations. It takes years to get representative and reliable results and therefore, final data analysis will not be available for many years.

1.7 RECOMMENDATIONS

The recommendations described here are specific to the project; their implementation could provide an improvement in the potash mine operations. It does not include all of the previously identified research needs in the potash industry.

The project is long term. Continuation of data acquisition is essential for creating a representative data base. It will take several years to collect sufficient data for a detailed and realistic analysis. Collection of data must and should be continued over the years until full ground/backfill equilibrium is achieved. The data should be analysed

using numerical modelling techniques. It is recommended that the necessary computer software be developed or available packages be modified and adapted for the analysis. The final analysis will include the performance of backfill in conjunction with different mining layouts, e.g. stress relief, room & pillar, longwall and shortwall mining, total extraction mining and their effect on subsidence.

Results can only be tested by field trials. It is recommended that a similar research program be tested in an active mining region, and that the optimization of extraction ratios using backfill be tested using the field data with appropriate numerical models.

1.8 PARTICIPANTS ON THE PROJECT

The participants on the project, on a joint venture basis, were:

- Central Canada Potash Division of Noranda Mines Limited (CCP)
- Centre de Recherche Noranda
- Potash Corporation of Saskatchewan Mining Limited (PCS Mining)

The project was initiated and partially funded by CANMET. Additional funding was provided by CCP and PCS-Mining.

Physical resources from the three participants were extensively used and a number of specialty contractors and research groups were also involved.

2 CENTRAL CANADA POTASH - A DIVISION OF NORANDA INCORPORATED

2.1 INTRODUCTION

Central Canada Potash is located approximately 76 Km (47 miles) southeast of Saskatoon, near the Yellowhead Highway.

Its shaft sinking operations began in 1965 and were successfully completed to potash in 1969. Two shafts having a nominal diameter of 4.9 metres (16 feet) were sunk to a depth of 1090 metres (3576 feet). The shafts were excavated through some 92 metres (302 feet) of clay, 366 metres (1200 feet) of shale, 153 metres (502 feet) of sand, shale, water and small amounts of coal, 406 metres (1332 feet) of assorted limestone shales and gypsum, 9 metres (30 feet) of salt, 3 metres (10 feet) of potash ore and 66 metres (217 feet) of assorted salt, potash and clay. The two shafts are 134 metres (440 feet) apart, one being used for production, and the other for service operations. The production shaft has a capacity of 568 tonnes of ore per hour (626 tons per hour).

The commercial production of potash at CCP started at the end of 1969 at a depth of 1021 metres (3350 feet) below surface. The potash

zone, which is presently mined, is approximately 3.35 metres (11 feet) thick. Stress relief with yielding pillars are used in the design of the mining layouts. The planned extraction ratio averages 35%.

Approximately 700 Km (435 miles) of underground openings have been developed to date. A total of eight continuous mining units are employed, including 5 Marietta miners, a Goodman Borer, an AM50 Voest Alpine and an AM100 Voest Alpine.

The mine and mill operate on a 24 hour a day, 7 day per week basis. Approximately 5 Km (3 miles) of roadway is cut per month. The mine is designed to produce approximately 3.3 million tonnes (3.6 million tons) of sylvinite per year to give approximately 1.3 million tonnes (1.4 million tons) of finished product (muriate of potassium) per year.

2.2 A BRIEF INTRODUCTION TO THE TEST AREAS

A generalized plan of the mining level is presented in Figure 1. The mine is subdivided in four blocks. Block I is mined out and the northeastern corner of Block II is being completed. Most mining operations are concentrated in Block III.

The research program is concentrated in two panels: Panel 109, located in Block I, and Panel 209, located in Block II.

Panel 109

Panel 109 is located in the northwest corner of Block I. It is an early hybrid room layout as illustrated in Figure 2. It was designed to be 490 metres (1610 feet) long, 61 metres (200 feet) wide and to have an effective mining height of 3.35 metres (11 feet).

During routine mining operations in 1974, brine was encountered. The inflow occurred along the central drift R24West and in the north wing W2. Mining was stopped at wing W3 and the panel was abandoned. The panel is only 61 metres (200 feet) long. Extensive support was installed in the area. A reinforced concrete bulkhead was also constructed in the panel as shown in Figure 2. The accessible areas in the panel are now only 1.2 metres (4 feet) high.

Prior to the initiation of this project the inflow was estimated at 14 lpm (3 lgpm). The current location of the inflow is also shown in Figure 2.

Panel 209

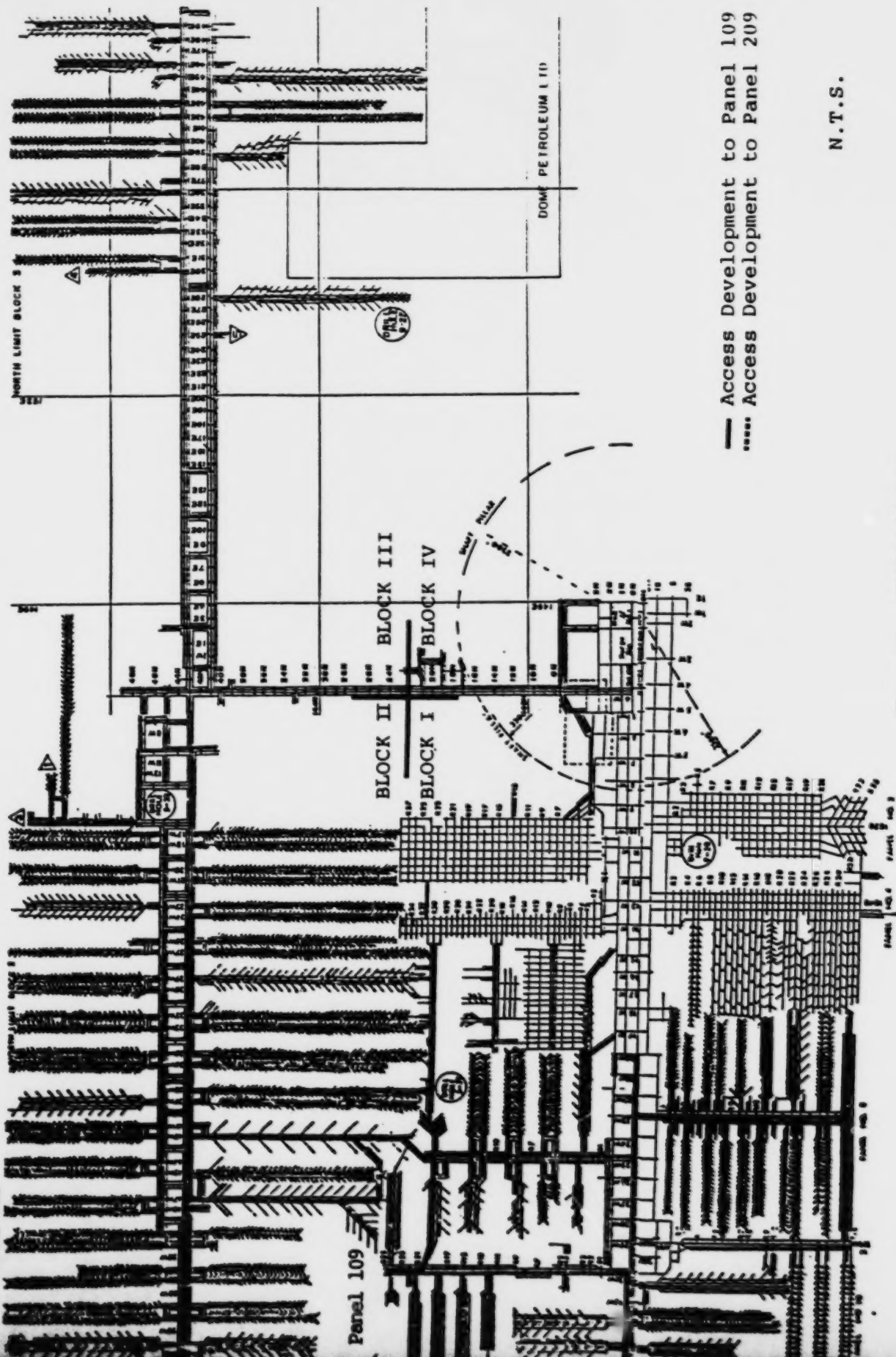
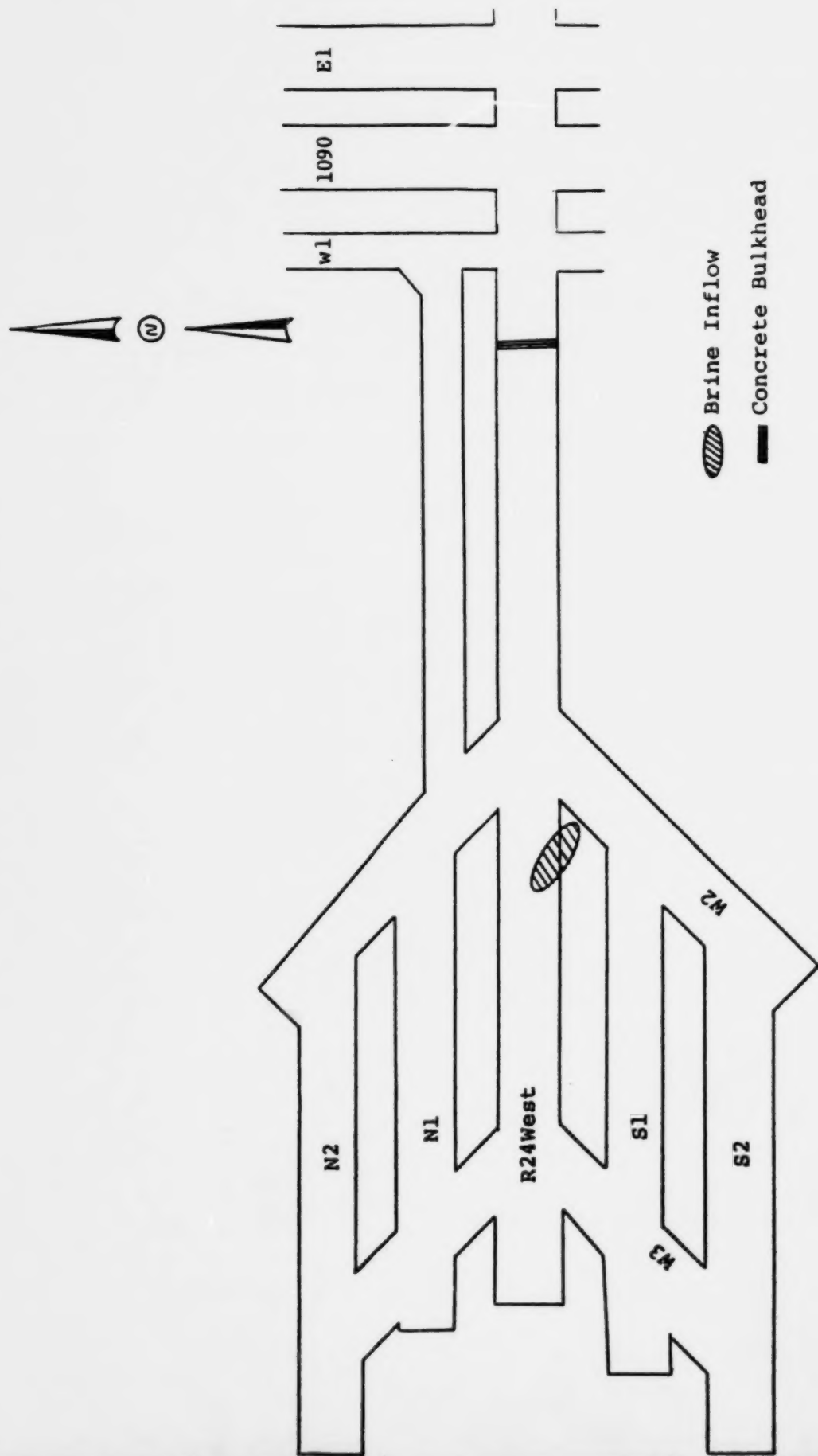


Figure 1. MINE LAYOUT

N.T.S.



 Brine Inflow
 Concrete Bulkhead

N.T.S.

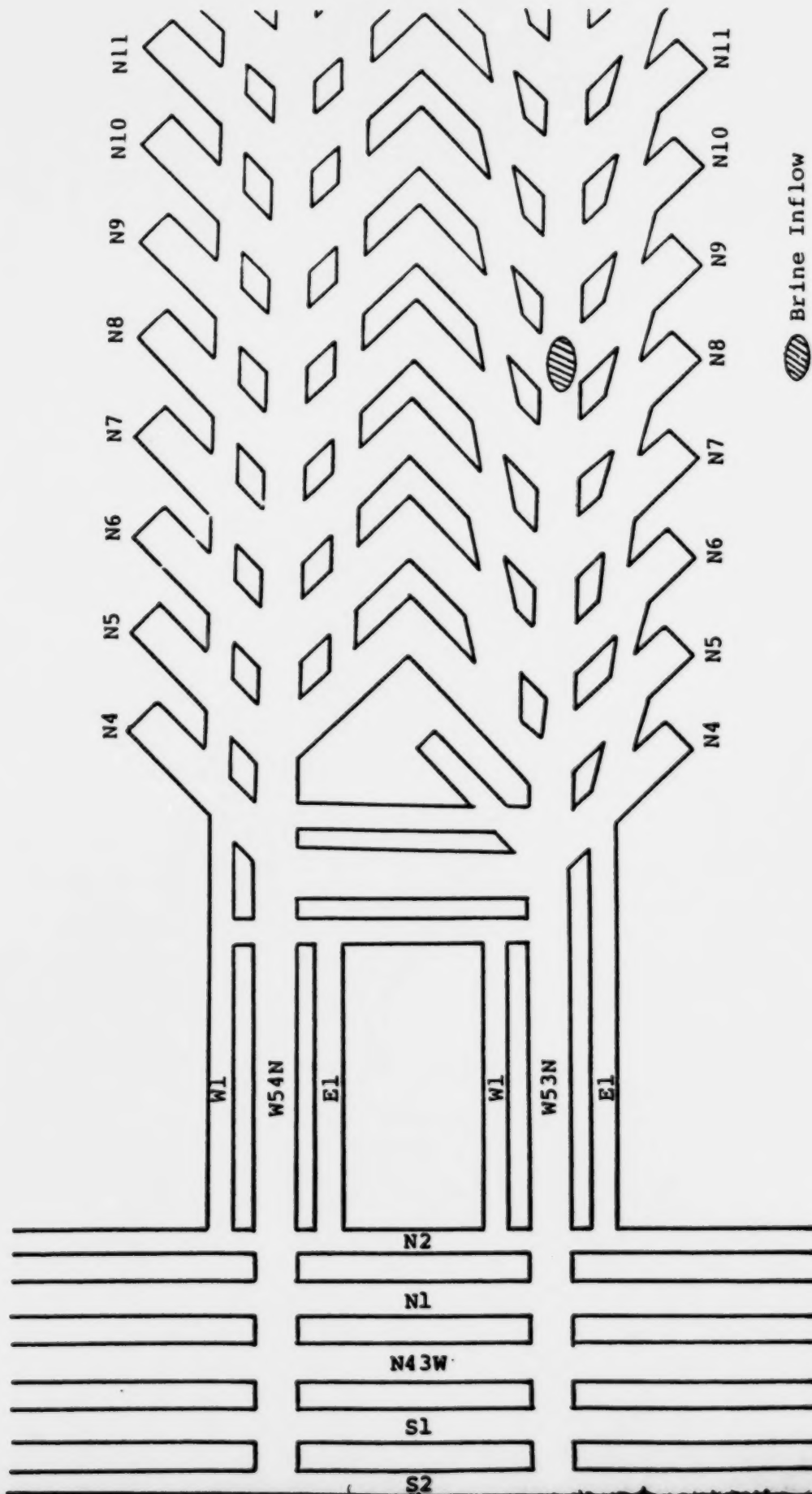
Figure 2. PANEL 109 LAYOUT

Panel 209

Panel 209 is located in the northwest section of Block II. It is a chevron room as illustrated in Figure 3. It was designed to be 914 metres (3000 feet) long, 128 metres (420 feet) wide and to have an effective mining height of 3.35 metres (11 feet).

In 1978, a brine inflow was discovered at wing N7 of room W53N and mining was stopped. Extensive support has been installed in the area since the occurrence of the inflow. Room W53N was only partially developed and is only 503 metres (1650 feet) long. Room W54N was developed to its designed length (914 metres-3000 feet). The current accessible areas in the panel are only .6 to 1.5 metres (2 to 5 feet) high.

The present location of the inflow is in wing N9, room W53N, as shown in Figure 3. The original inflow was approximately 227 lpm (50 lgpm) and prior to the initiation of this project it was estimated at 82 lpm (18 lgpm). An 89% reduction of the brine inflow rate was achieved.



N.T.S.

Figure 3. PANEL 209 LAYOUT

2.3 DEVELOPING ACCESS TO THE TEST AREAS

An easy and safe passage to panels 109 and 209 had to be developed and maintained during the years.

Rehabilitation work is a continuous effort to control ground closure, floor heaves and pillar slabbing. Rehabilitation work has been performed using an Alpine Miner AM50 supported by scoop trams for haulage. A total of 2900 metres (9500 feet) of access to Panel 109 and 2200 metres (7200 feet) of access to Panel 209 were rehabilitated. This is shown in Figure 1.

Access into the panels was maintained in preparation for the drilling, grouting, instrumentation and backfill programs. Approximately 670 metres (2200 feet) of access was developed in Panel 209, and approximately 457 metres (1500 feet) developed in Panel 109.

3 GEOLOGY AND MINE STABILITY

3.1 GEOLOGY

A column section showing the geology of the Devonian Formations in the Saskatchewan area is shown in figure 4.

The basal carbonate unit of the Middle Devonian Upper Elk Point is named the Winnipegosis Formation. The Winnipegosis interval is composed of reef and non-reef carbonate ranging from less than 15 meters (50 feet) thick in the inter-reef areas to more than 180 meters (590 feet) in the thickest reef sections. The main formation is composed of either structureless vuggy dolomite containing corals, stromatoporoids, algae and some relict oolites and pisolites, or a cryptocrystalline to microcrystalline, poorly fossiliferous dolomite containing fine pseudo-oolites. The Winnipegosis Formation is a water bearing formation.

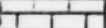
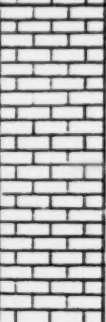
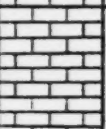
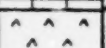
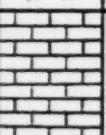
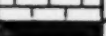
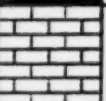
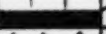
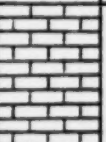
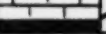
The Prairie Evaporite Formation disconformably overlies and forms a cover of 76 to 210 metres (250 to 690 feet) over the Winnipegosis Formation. The Prairie Evaporite Formation was formed by evaporation of a dead sea, the Elk Point Basin, in which anhydrite and halite beds

accumulated rapidly on top of the marine limestones of the Winnipegosis Formation.

Potash beds commonly occur interbedded with halite near the top of the Prairie Evaporite section. They were the result of the continuing evaporation of the basin, in which potassium was deposited as sylvite. Sylvite and carnallite are the most common potash minerals present. The potash occurs in essentially flat-lying beds and at a depth of approximately 1100 meters (3600 feet) in the Saskatoon area.

The Second Red Bed member at the base of the Dawson Bay Formation consists of a very poorly consolidated reddish-brown dolomitic shale. It overlies the Prairie Evaporite and was the result of the deposition of muds of the incoming Dawson Bay Sea.

The base of the Dawson Bay Formation consists of fine grained argillaceous limestone overlain by highly fossiliferous, pseudo-oolitic and fragmental carbonates that commonly contain large stromatoporoids. The Dawson Bay Formation contains localized pockets of brine and may be interconnected with the waters from the overlying water bearing formations.

LITHOLOGIC DESCRIPTION			FORMATION	PERIOD	
DOLOMITE & LIMESTONE			BIRD BEAR	DEVONIAN	
DOLOMITE AND LIMESTONE			DUPEROW		
DOLOMITE AND LIMESTONE			SOURIS RIVER		
ANHYDRITE		DAVIDSON EVAPORITE			
DOLOMITE					
RED DOLOMITIC SHALE		1ST RED BEDS			
DOLOMITE AND LIMESTONE			DAWSON BAY		
RED DOLOMITIC SHALE		2ND RED BEDS			
SALT		POTASH	PRAIRIE EVAPORITE		ELK POINT GROUP
DOLOMITE			WINNIPEGOSIS		
RED DOLOMITIC SHALE		3RD RED BEDS	ASHERN		
DOLOMITE				SILURIAN	

ELK POINT GROUP

Figure 4. GEOLOGY OF THE DEVONIAN FORMATIONS IN THE SASKATOON AREA

3.2 GEOLOGICAL ANOMALIES AND MINE STABILITY

The continuity of the flat-lying potash beds at CCP and the seal provided by the salt back to water ingress is sometimes disturbed by the occurrence of geologically anomalous structures.

The most commonly occurring anomalies are known as washouts, salt horses, leached zones, collapse structures and the thinning of the Prairie Evaporite due to Winnipegosis mounds. The anomalies vary from relatively small barren zones and channel-like features within the ore zone, through major collapses of the overlying evaporite and limestone formations. Anomalies may contain brine or serve as pathways for brine. Anomalies not only affect ore grade but greatly influence the development and effectiveness of the mining operations.

Naturally, the safety of workers, the possibility of mine flooding and the cost factor involved with the prediction, prevention and control of such occurrences are major concerns of the potash mining industry.

3.3 WATER SOURCE IN BLOCKS I AND II

A series of studies has been performed in an attempt to determine the source of brine entering Panels 209 and 109. These studies involved exploration drilling, analysis of core logs, drill stem tests, electromagnetic testing for brine, review of seismic surveys and brine chemical tests. Typical brine chemical analysis results obtained in 1985 are presented in figure 5.

The investigations have indicated that the most probable source of brine inflow in Panels 190 and 209 is the Dawson Bay Formation. There also exists the possibility of water from higher horizons. The Colonsay collapse structure, a north-easterly trending collapse of the Dawson Bay Formation, occurring west of the mine, may be a possible influence.

3.4 HISTORY OF FLOW IN PANEL 109

In 1974, during routine mining operations in panel 109 a brine inflow was encountered. The inflow occurred from open tension cracks along the central drift and the north wing. Additional inflows developed in tension cracks occurring in the relief drifts and along yield pillars. The

inflow increased rapidly and mining was stopped. A reinforced concrete bulkhead was constructed and a pumping program initiated.

The brine was found to be saturated in sodium chloride. Brine was found in the Second Red Beds flowing along fractures and separations or along clay seams in the salt back, leaking in a number of places in the panel. A grouting program of the salt was initiated, with limited success.

Since its occurrence, Panel 109 flow rate increased with time due to the deteriorating ground conditions, until the Panel 209 inflow occurred. The Panel 109 flow rate then decreased from 91 lpm (20 lgpm) to a flow of 14 lpm (3 lgpm). The decrease of the flow has been attributed to a common source to both Panel 109 and 209 inflows.

During the years, the inflow has dropped from a maximum of 105 lpm (23 lgpm) in 1976 to approximately 14 lpm (3 lgpm), taken prior to the initiation of this project. A graph of brine flow in Panel 109 versus time is presented in Figure 6.

	PANEL 209		PANEL 109	
	$\mu\text{G/ML}$	epm	$\mu\text{G/ML}$	epm
$\text{CO}_3^{=}$	28	1		
HCO_3^{-}	262	4	29	0
$\text{SO}_4^{=}$	541	11	495	10
Cl^{-}	198528	5600	196667	5547
Br^{-}	680	9	845	11
Ca^{++}	16236	810	13714	684
Mg^{++}	1972	162	3980	328
Na^{+}	104632	4551	102404	4452
K^{+}	3682	94	3820	98
Sr^{++}	334	8	293	7
TDS	326895		322247	
pH	8.6		6.3	
Specific Gravity	1.208		1.201	
Na:Cl		0.813		0.803
(Na+K):Cl		0.829		0.820
(Cl-Na):Mg		6475		3.343
Cl:Br		657.971		525.528
Ca:Mg		4.992		2.089

Figure 5. TYPICAL BRINE CHEMICAL COMPOSITION FOR PANELS 109 AND 209

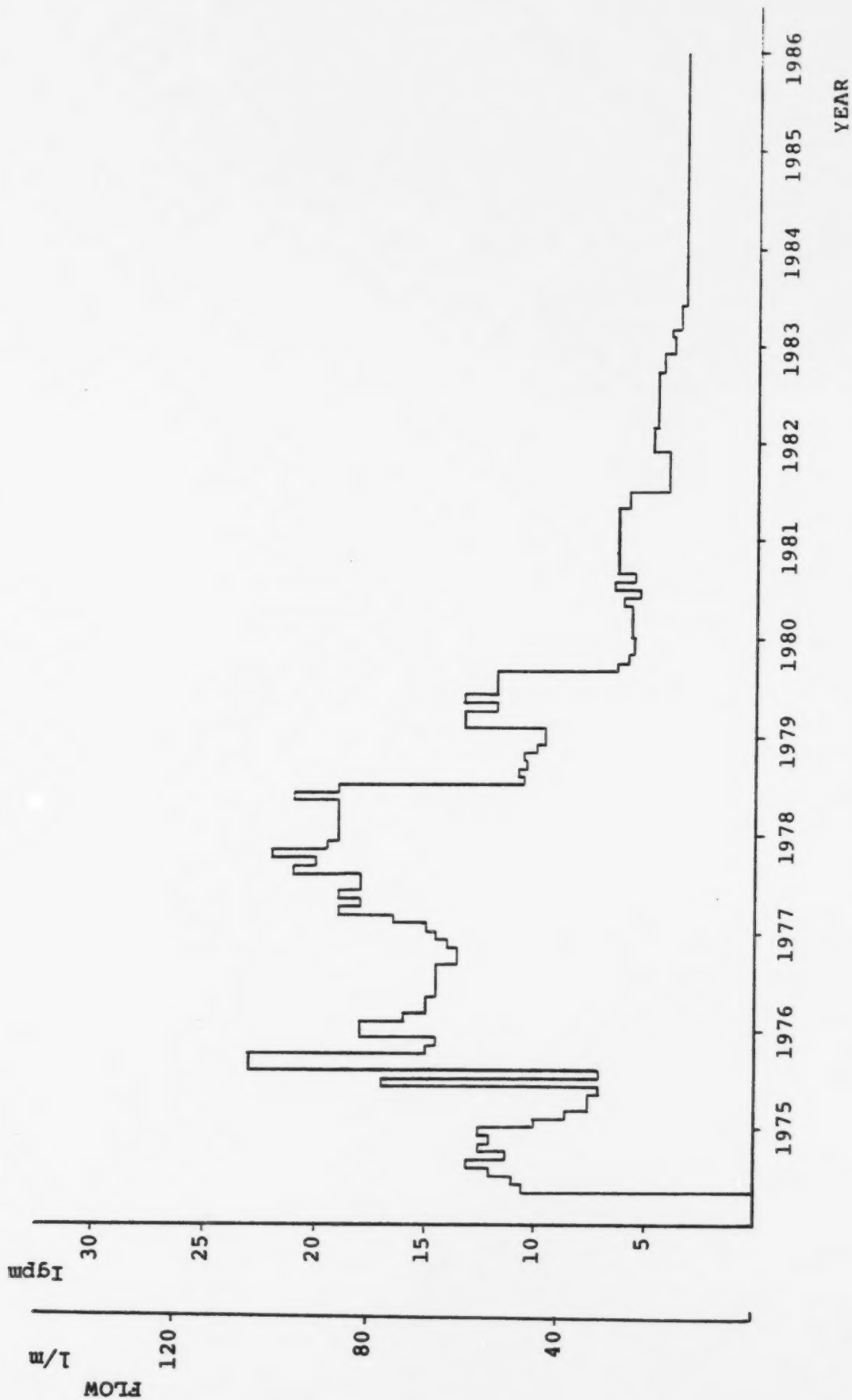


Figure 6. ROOF BRINE FLOW RATES - PANEL 109

3.5 HISTORY OF FLOW AND POSSIBLE CAUSES - PANEL 209

In 1978 water was discovered at wing N7 of room W53N and quickly increased in volume with subsequent roof instability. At the time, mining was being carried out 503 metres (1650 feet) to the north of the inflow area. Mining was stopped and the equipment relocated. Slight amounts of hydrogen sulphide gas occurred in the inflow zone and the ventilation to the area had to be improved. New leaks developed in tension cracks in other wings. Extensive roof collapses occurred, the roof deterioration being associated with the inflow.

Since then, new leakages have developed and some have dried up. The relocation of the inflow is associated with the shortening of the path between the Dawson Bay and the mine openings. The present location of the inflow is in wing N9, room W53N. The initial inflow was estimated at 227 lpm (50 lgpm).

A monitoring program was initiated and back support was installed to arrest the rate of roof deterioration in the immediate area. Diamond drilling has shown that there is a thin salt cover present and a high clay content in the immediate mining back. Closure rates in the order of 7.6 cm/100 days (3 inches/100 days) have occurred and the ground movement has damaged the installed support. Chemical tests indicate a similar composition to the brine occurring in Panel 109.

Since its occurrence, the flow in Panel 209 has varied considerably, with the highest estimated rate being 341 lpm (75 lgpm) in 1981. A grouting program undertaken during 1981 reduced the flow in Panel 209 to 91 lpm (20 lgpm) but did not affect the flow in Panel 109. Since then, the flow in Panel 209 has decreased and the grouting has resulted in an increase in pressure. Prior to the start of this research program the brine inflow occurring in Panel 209 was estimated at 82 lpm (18 lgpm). A graph of brine flow in Panel 209 versus time is presented in Figure 7.

The flow in Panel 209 has been associated both with past flexure followed by cracking of the overlying strata, and by further fracturing induced by mining, which may have allowed brine to migrate from the Dawson Bay, through the Second Red Beds and through the thin salt cover in the area.

It is believed that any one or a combination of the following effects have contributed to the existing ground conditions in Panel 209: a local mound present in the underlying Winnipegosis Formation, a local ridge in the area having a NE/SW trend, a thinning of the salt back, high clay concentrations in the back, higher than normal local extraction, and the Davidson Evaporite is missing above both areas.

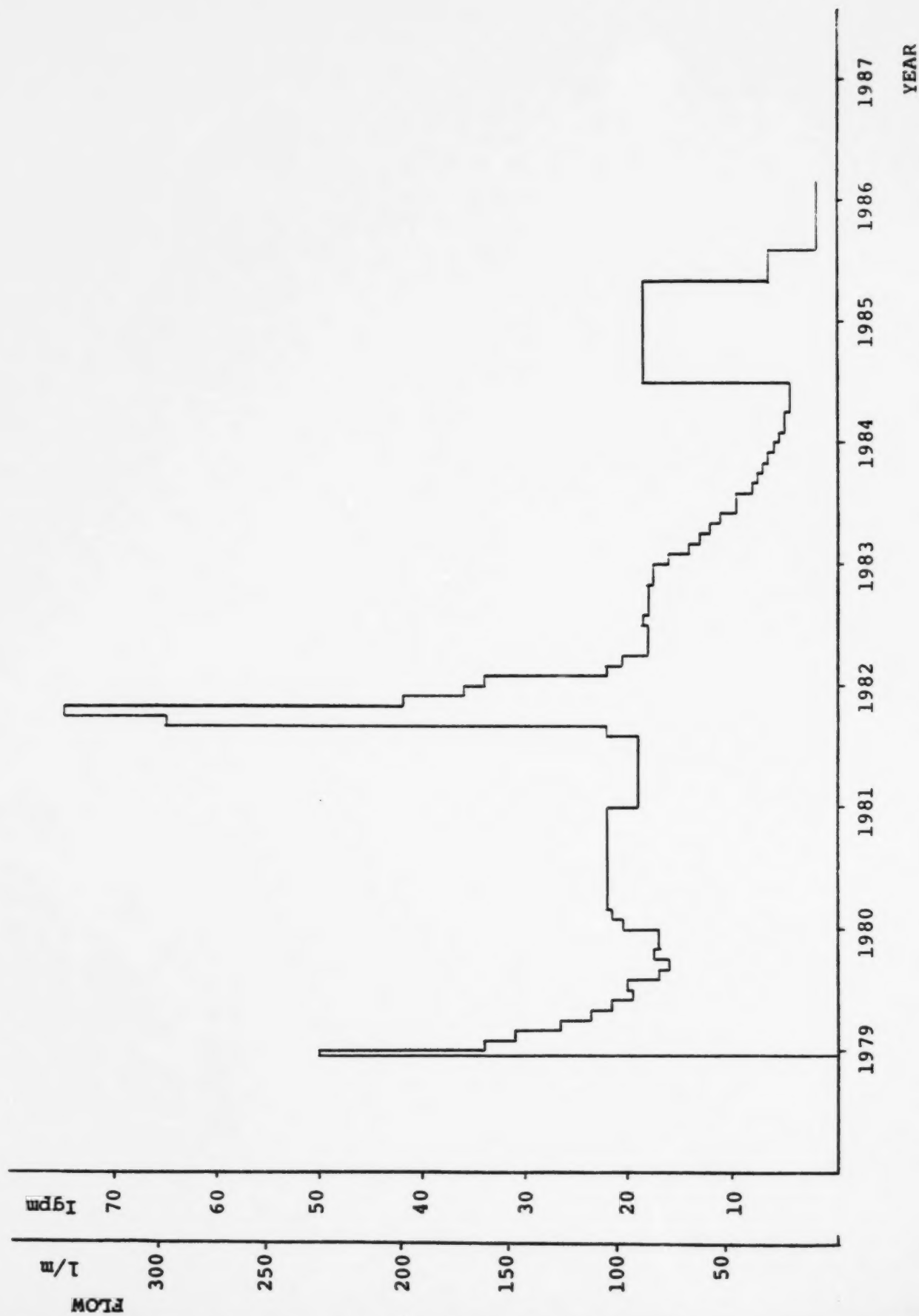


Figure 7. ROOF BRINE FLOW RATES - PANEL 209

3.6 FACTS AND FIGURES ON THE PROBLEMS ENCOUNTERED IN PANELS 109 AND 209

The following observations summarize the brine inflows in Panels 109 and 209:

1 - the most probable source of brine inflow in Panels 109 and 209 is the Dawson Bay Formation as indicated by underground exploratory drilling and testing and surface drill hole well-stem tests.

2 - Although the brine may come from localized formation water in the Dawson Bay, there is probably a flow connection with other overlying water bearing formations.

3 - Panels 109 and 209 flows may be inter connected.

4 - total closure rate in Panel 209 was estimated at 7.6 cm/100 days (3 inches/100 days), indicating that the prime cause of closure was parting of the overlying strata along clay seams rather than creep.

5 - the brine flows have gradually decreased over the years, although grouting in Panel 209 has had a major influence.

6 - the two inflows occurred in the north west of the mined out areas, which is located 6.5 Km (4 miles) from the east flank of the Colonsay Collapse Structure.

7 - the two inflows are located under an area where the Davidson halite is missing.

4 DESIGNING A RESEARCH PROGRAM FOR CCP

4.1 INTRODUCTION

The research program was designed to achieve the following objectives: develop the data base necessary to understand the effectiveness of backfill in terms of control of local and regional mine stability in the long term, control of creep deformation and subsidence, control of brine inflow, performance as a local and regional ground support system; study and analyse the creep and failure characteristics of potash and salt; study the in-situ long term behaviour of the Dawson Bay during mine closure.

Diamond drilling and field instrumentation formed the core of the field work, which is summarized in the following section.

A laboratory program was designed to investigate the physical characteristics of the mine rock formations and salt backfill (see section 4.3).

4.2 THE FIELD WORK

The field work in Panels 109 and 209 was designed to use the diamond drill holes, which were placed for grouting purposes, and to instrument selected sections of the areas, which were planned to be backfilled.

The basic steps involved in the above sequence are summarized below:

1 - rehabilitate the accessways to the panels. The access to the inflow areas deteriorates rapidly due to parting of the salt and creep. CCP's policy has been to maintain safe access to the inflow areas so that continuous long term monitoring and control of the inflow can be performed. The cost associated with the maintenance of access, brine pumping and testing has been considerable.

2 - drill a series of holes in the inflow areas and study the brine flow characteristics.

3 - grout off the Dawson Bay Formation to control and eliminate, if possible, the inflow.

4 - instrument the rock formations and backfill zones.

5 - backfill the test areas to reduce the room closure rate and ground subsidence, and to control the deformation behaviour of the Dawson Bay.

6 - continue to observe the area and collect data along with subsidence records.

4.3 THE LABORATORY WORK

An extensive program of laboratory tests was designed to determine the basic physical characteristics of both the mine formations and the backfill. The testing program was conducted in the Rock Mechanics facilities of Queen's University.

The Dawson Bay, First Red Bed and Second Red Bed Formations were core sampled and laboratory tested. Brazilian tests and uniaxial and triaxial compression tests were conducted using a Material Testing System (MTS) Model 810 Servo Controlled Compression Load Frame. A total of 340 tests were performed at Queen's University (other tests were conducted by the Centre de Recherche Noranda, CANMET and the University of Manitoba and are included in other reports). The test

procedures and results are described in detail in Appendix A. A summary of results is listed below.

- Dawson Bay:

Tensile strength	-	11 ± 2.8 MPa (1600 ± 400 psi)
Compressive strength	-	124 ± 25 MPa (18000 ± 3600 psi)
Young's Modulus	-	31026 ± 7580 MPa ($4.5 \pm 1.1 \times 10^6$ psi)
Poisson's Ratio	-	0.13 ± 0.04
Cohesion	-	20.7 MPa (3000 psi)
Angle of failure	-	71 ± 2.6 degrees
Friction angle	-	52 ± 5.2 degrees

- 1st Red Beds:

Tensile strength	-	7 ± 1.4 MPa (1016 ± 204 psi)
Compressive strength	-	64 ± 7 MPa (9300 ± 1080 psi)
Young's Modulus	-	17237 ± 1379 MPa ($2.5 \pm 0.2 \times 10^6$ psi)
Poisson's Ratio	-	0.08 ± 0.02
Angle of failure	-	75 ± 4 degrees
Friction angle	-	60 ± 8 degrees

- 2nd Red Beds:

Compressive strength	-	41.4 ± 6.7 MPa (6000 ± 968 psi)
Young's Modulus	-	17721 ± 2758 MPa ($1.7 \pm 0.4 \times 10^6$ psi)
Poisson's Ratio	-	0.17 ± 0.08
Angle of failure	-	62 ± 8 degrees
Friction angle	-	34 ± 15 degrees

The backfill laboratory tests are under way. A total of 90 tests are proposed as described in Appendix B.

5 THE RESEARCH WORK IN PANEL 209

5.1 REVIEW OF PREVIOUS WORK

Following the initial inflow in 1978 in Panel 209 extensive timber cribbing and posting was undertaken to provide temporary support to the back in the area. Since the inflow, pumping of brine to the shaft and to the surface has been a continuous operation. Rehabilitation and ground monitoring programs were also initiated. High closure rates, in the order of 7.6 cm/100 days (3 inches/100 days) have characterized the abnormal ground behaviour in the area. These rates were measured in 1980 and 1981, when closure rates could be expected to be 1.8-2.5 cm/100 days (0.7-1.0 inch/100 days).

In 1979 an exploratory drilling program was established to investigate the geology and brine source. Core recovery from the drill holes indicated that the salt formation between the mine back and the Second Red Beds was thinner than usual by 1.8 m (6 feet). This program also showed that the most probable source of brine inflow in the area is the Dawson Bay Formation. By 1984, ground movement had damaged the timber support, partially limiting access to the panel, leaving the acces-

sible areas with a vertical height varying from .6 to 1.5 meters (2 to 5 feet).

A monitoring program of chemical composition, specific gravity, pH level, temperature, brine formation pressure and brine flow was initiated with the inflow and has continued to the present. The brine properties have not changed markedly over the years. Typical brine chemical test results are presented in figure 5. From an initial inflow of approximately 227 lpm (50 lgpm) it has varied considerably to a high of 341 lpm (75 lgpm) in 1981. A grouting program was conducted at that time reducing the inflow to 91 lpm (20 lgpm). Prior to the initiation of this project the inflow was estimated at 82 lpm (18 lgpm). A graph showing the variation of brine flow with time is presented in figure 7.

5.2 REHABILITATION OF ACCESSWAYS TO PANEL 209

Closure effects in Block 2 have resulted in continuous rehabilitation of accessways. Most of the rehabilitation work was performed using a Voest-Alpine AM50 and a 3.8 cu.m. (5 cu.yard) scooptram. Rehabilitation consisted of trimming walls and cutting floors. Cutting into the back to competent ground was also undertaken when roof deterioration was evident. Roof bolting and slotting were done in more critical areas.

Blasting was used to eliminate major pillar slabs and manual scaling was performed on a daily basis. The rehabilitation of access to Panel 209 involved approximately 2200 metres (7200 feet) of cutting, see Figure 1.

5.3 REHABILITATION WORK IN PANEL 209

The rehabilitation work within Panel 209 has been completed. It achieved the following objectives: to provide access to the inflow zone so that a monitoring program could be undertaken during drilling and grouting; to prepare the diamond drill stations; to prepare the instrumentation stations; to prepare the room for the backfilling operation; to establish adequate ventilation to the area.

Approximately 670 metres (2200 feet) of access into the test areas were developed. The access was cut in the salt formation, above the old mine back, to a height of approximately 3.35 metres (11 feet), where stable roof conditions are encountered, as illustrated in Figure 8. In the figure, it will be noted that the floor is loose muck obtained from the cutting, which then partially backfills the old openings.

A layout of the cutting performed in Panel 209 is shown in Figure 9. The access to the inflow area was cut from W54N to W53N and reached

the inflow from the North. Five diamond drilling stations were prepared during the cutting operations and a sump located at W54N11. The brine flow from the diamond drill holes was measured in preparation for the grouting program.

5.4 THE GROUTING PROGRAM IN PANEL 209

A drilling and grouting program was prepared to control and ultimately seal the brine inflow in Panel 209, in preparation for the back-filling operation. Four basic steps can be distinguished in the program: drilling of primary grout holes, primary grouting, drilling of secondary grout holes, and secondary grouting.

The primary drilling program was designed to locate a curtain of grout in the Dawson Bay around the inflow. It was to be anchored to the North and South by the abutment pillar to the East of the room.

Figure 10 presents a plan showing the primary hole layout. The holes are equidistant from one another. The hole pattern was selected to intersect the main water bearing horizon in the Dawson Bay at equidistant locations around the inflow site. All holes were collared over pillars, with blow out protection. Standard precautions are as follows:

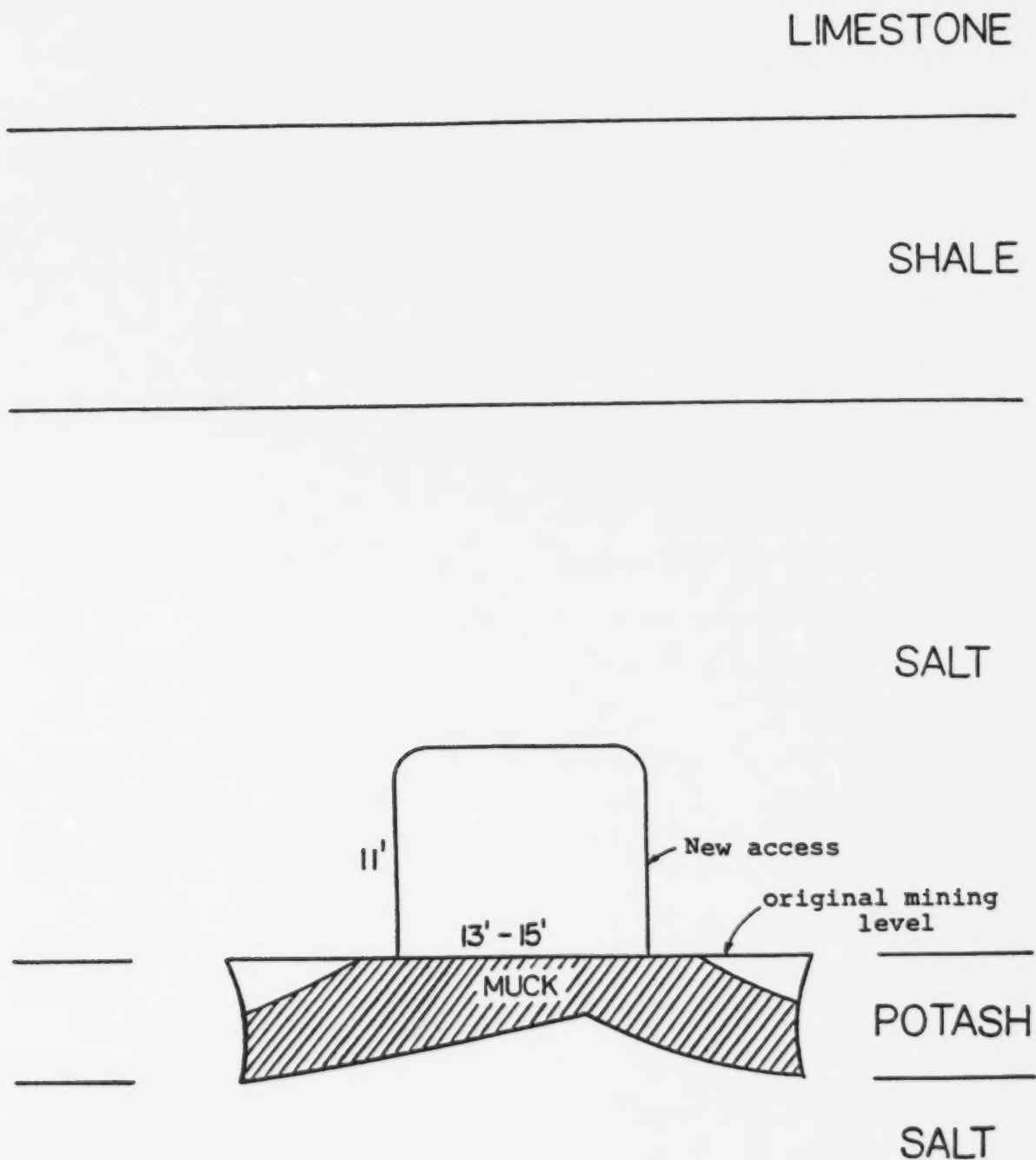


Figure 8. REHABILITATION OF ACCESS INTO PANEL 209 - CROSS SECTION

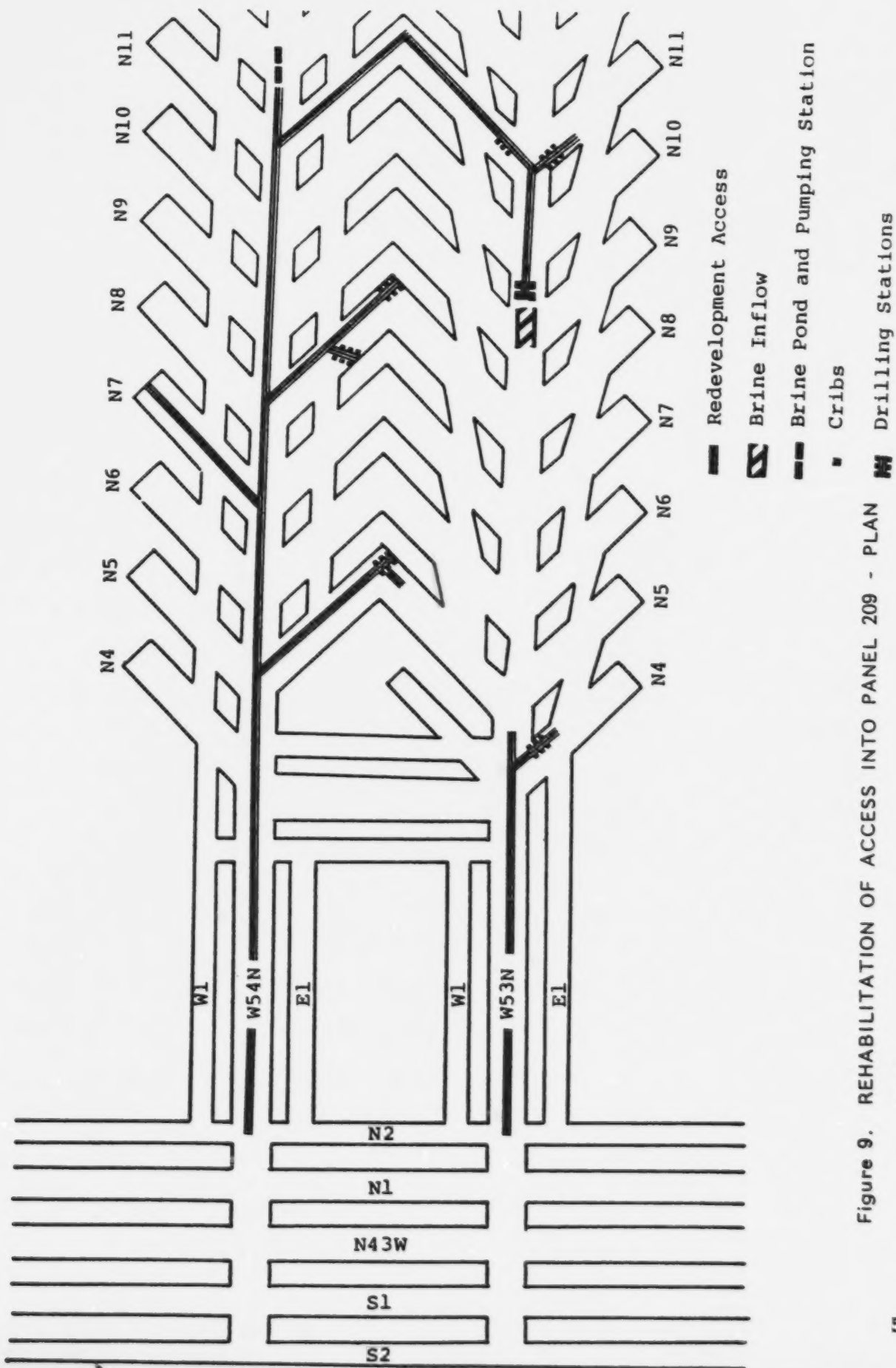


Figure 9. REHABILITATION OF ACCESS INTO PANEL 209 - PLAN VIEW

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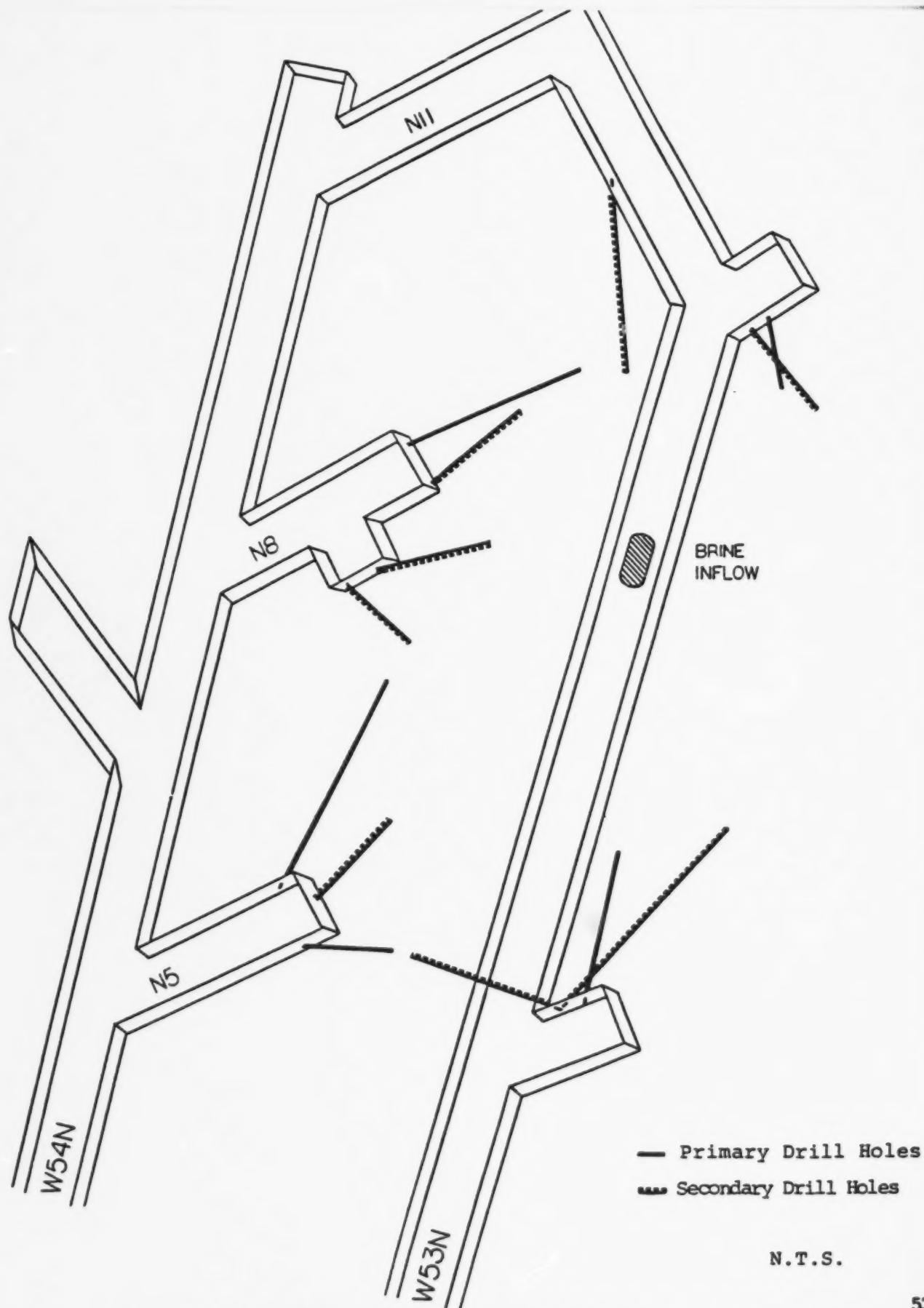


Figure 10. PRIMARY AND SECONDARY EXPLORATORY HOLE LAY-
OUT - PANEL 209

Drill 2.4 metres (8 feet) install 2.4 m (8 feet) packer and brine test to 3450 KPa (500 psi). Drill 4.9 metres (16 feet) install 4.9 m packer and brine test to 10340 KPa (1500 psi). Core along the dip until the vertical elevation above the mine back is 9.1 metres (30 feet). Install and grout the required length of NW casing and wait 24 hours. Test NW casing to 10340 KPa (1500 psi). Core through the remainder of the salt back and the Second Red Beds to the BW anchor point. This point is determined geologically, as the transition from dolomitic mudstone to competent limestone. Install and grout BW casing and wait 24 hours. Test BW casing to 13790 KPa (2000 psi). Core to water bearing fractures.

All holes were used in flow/pressure tests to estimate the number of fractures and fracture size in the water bearing zone. Dye tests showed a north-easterly brine flow direction. Brine sampling was also performed to determine the brine chemical composition. The brine was found to be saturated with sodium chloride, see Figure 5. The inflow in Panel 209, prior to grouting, was estimated at 82 lpm (18 lgpm). High early cement was selected as the most suitable grout because it sets quickly. The roof brine was used to prepare the grout; the grout setting times were not significantly affected by the presence of the salt solution.

In order to obtain the most effective seal in the water bearing zones each hole was grouted individually and in a selected sequence, starting with the holes having higher brine flow rates. The brine/cement grouts

were prepared at varying ratios starting with a quarter bag mix in 182 litres (40 l. gallons) and ending with 1 to 2 bags in 182 litres.

The grouting technique was designed to place a cement curtain between each of the primary drill holes and the inflow site by opening adjacent drill holes until the brine drew the cement to the hole. Grouting pressures were designed to exceed the brine pressures in the area, but were carefully controlled so as not to cause hydrofracturing of the overlying formations. They started at 0 KPa and were allowed to increase to 6895 KPa (1000 psi). A continuous grout cover was thus established in the Dawson Bay Formation forming a curtain. The 1984-85 cement grouting program, using the primary holes, reduced the total inflow from 82 lpm (18 lgpm) to approximately 27 lpm (6 lgpm).

Having completed the above grouting program with success, the pattern and number of secondary holes for chemical grouting was selected. Figure 10 shows the secondary grout hole layout. The secondary holes are located between the primary holes. The main purposes of the secondary holes were to verify the effectiveness of the primary grout curtain and to seal the rock formation by filling the remaining fine fissures. A series of chemical grouts were considered including prepolymers, polymers, polyurethanes, acrylics and acrylamides. A grout commonly known as Avanti AV100 was selected after testing of grout gel reactions in saline conditions, gel quality, and gel times. This secondary grouting program effectively sealed off the finer fissures

through which the brine was still flowing into the panel and its success can be measured by the reduction in inflow from 27 lpm (6 lgpm) to approximately 9 lpm (2 lgpm).

The area is under continuous surveillance. Two additional holes provide drainage and pressure relief for the area, to ensure that the grout curtain remains intact and that the brine does not break into the mine workings in another location.

5.5 THE INSTRUMENTATION PROGRAM IN PANEL 209

A detailed study was undertaken to establish the most appropriate instrumentation program for Panel 209.

The instrumentation program was designed to establish the following objectives: to gather information on the long term behaviour and effectiveness of the grout/backfill system as a mechanism of brine inflow control; to gather information on the effectiveness of salt backfill as a support mechanism, and as a mechanism to control local and regional mine stability, to limit creep deformation and to control ground subsidence; to evaluate the load deformation characteristics of the surrounding strata in the test panel; to evaluate the in situ long term behaviour of the

Dawson Bay during mine room closure; to evaluate the creep and failure characteristics of potash and salt; to develop a data base which would serve for future studies and development of new design criteria for alternative mine layouts and optimum mining strategies.

The first part of the instrumentation program involved a study of the strata in Panel 209. The understanding of the structure of the geological formations was extremely important on the selection of the most suitable instruments and on the design of the instrumentation stations for the area. Information was gathered from previous studies undertaken in the mine, and included geophysical evaluations, geologic maps and exploration drill logs. The extensive core drilling performed in preparation for the grouting program in Panel 209 provided the necessary information on the geology of the area.

A series of structural and stratigraphic cross sections were constructed to indicate the specific geology of the mine area in Panel 209 and to explain the structure and conditions encountered. The depths of the contacts were established, the local thickening and thinning of the intervals were characterized. The type and extent of the fracture system in the strata was established, and the clay seam configuration occurring in the area was determined. A simplified structural cross section for Panel 209 showing the formation thicknesses and the clay seam configurations is presented in Figure 11. The depths shown are related to the back elevation in the old mine workings.

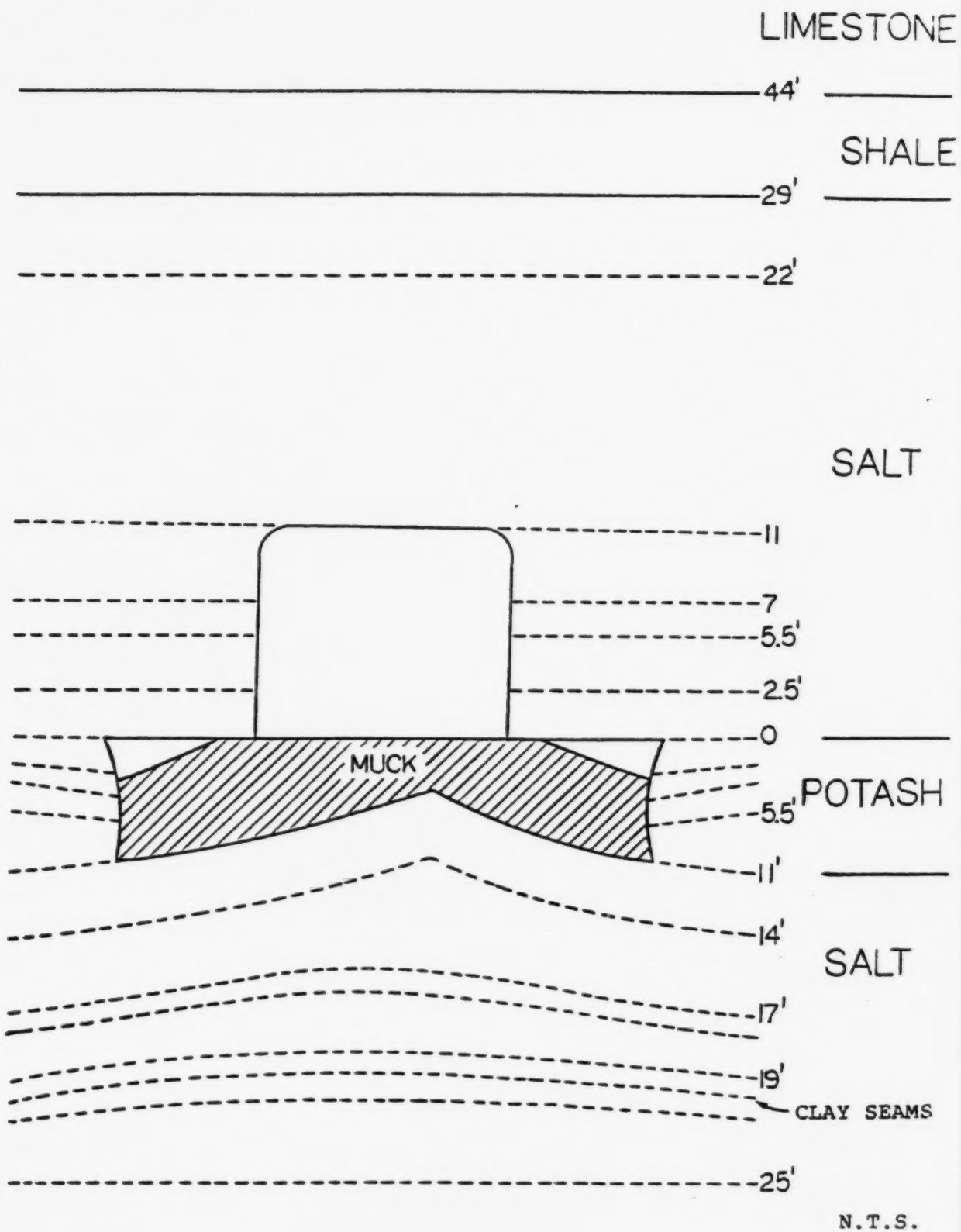
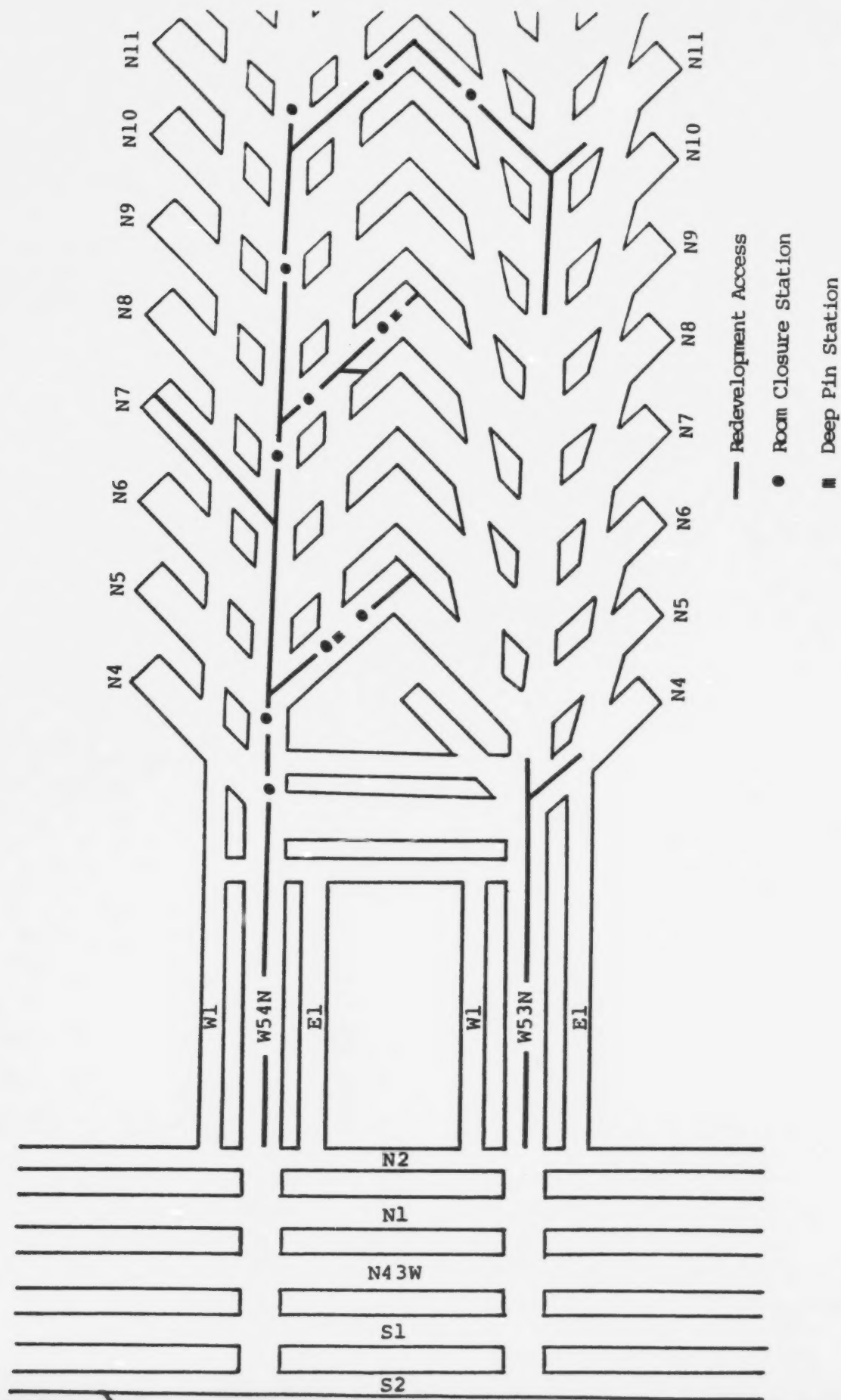


Figure 11. SIMPLIFIED STRUCTURAL CROSS SECTION - PANEL 209

The instrumentation program was based on the findings of the local geology and was designed to provide the most detailed information on the interaction of the backfill with the surrounding formations. This was important for the prediction and control of the deformation of the strata in the area.

To monitor the stress changes and related closures in the backfill and surrounding strata a series of temporary and permanent instrumentation stations were developed. The temporary stations consisted of room closure pin stations and deep pin stations. They were used to monitor ground closure stability and room closure rates in Panel 209 prior to backfilling. Eleven room closure pin stations and two deep pin stations were installed in Panel 209. The location of these stations is shown in Figure 12.

The room closure stations consisted of 3 or 5 hilti pins installed on the roof and walls of the opening. A tape extensometer was used for reading the vertical and horizontal changes in dimension of the rooms. These stations have established vertical and horizontal closure rates in Panel 209 averaging 0.76 cm/100 days (0.3 inches/100 days) and 1.24 cm/100 days (0.49 inches/100 days), respectively. Typical curves of vertical and horizontal closures with time are presented in Figure 13. These stations were also used to monitor possible ground instabilities induced by the operational activity. No change in room closure rates was detected during the grouting activities.



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Figure 12. TEMPORARY INSTRUMENTATION STATION LAYOUT -

PANEL 209

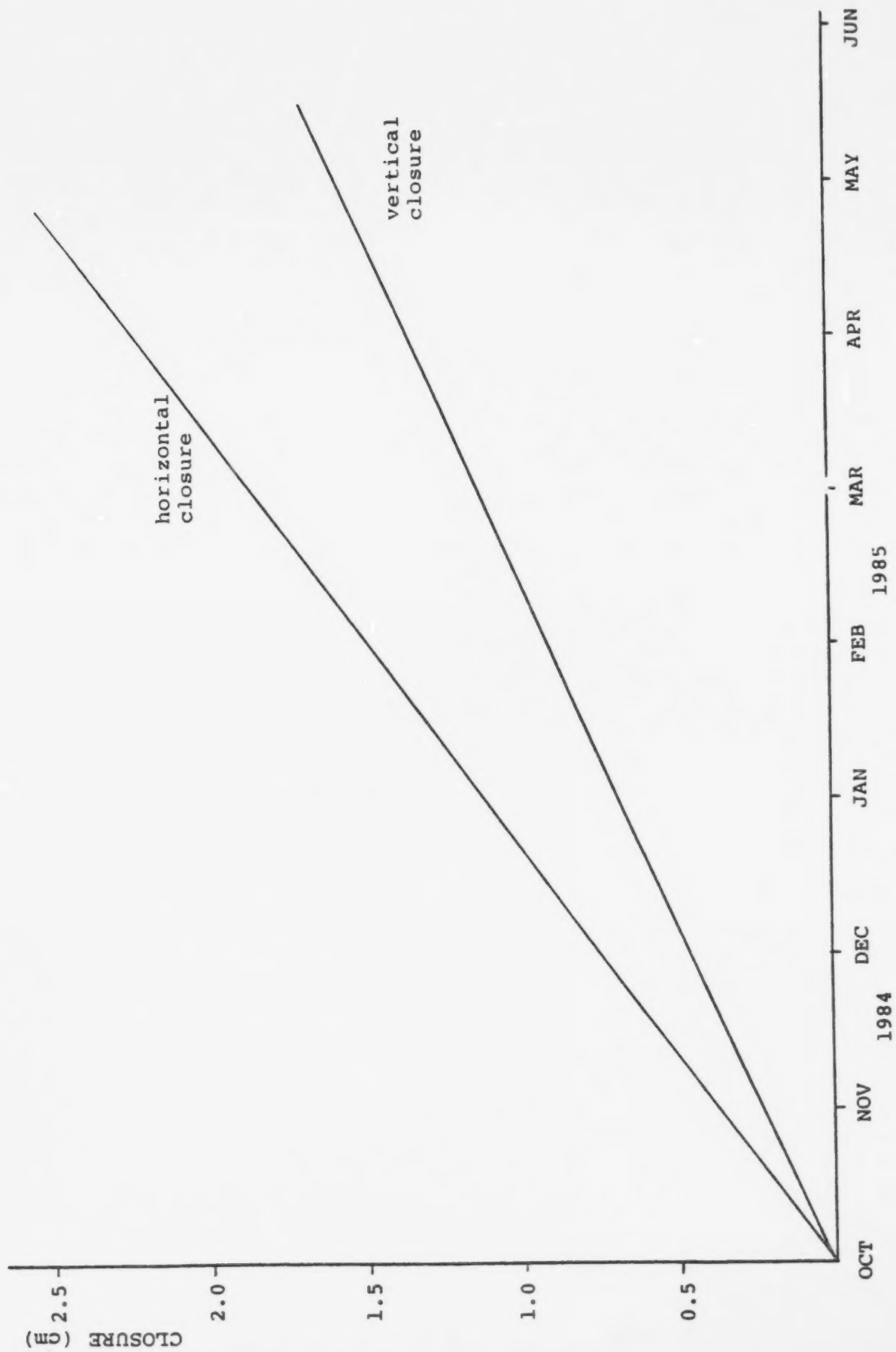


Figure 13. ROOM CLOSURE VS TIME - PANEL 209

The deep pin stations consisted of four mechanical bolts anchored at different depths in the salt back as illustrated in Figure 14. These stations were used to monitor clay seam separation and ground instability in the vicinity of drill stations, and as a warning tool of roof failure initiation due to grouting. These stations have indicated no clay seam separation or ground instability before or after the grouting program.

Permanent instrumentation stations were also designed to study the interaction of the backfill with the surrounding strata as follows: to provide information on the long term deformation behaviour of the host salt formation above and below the mine openings before and after backfilling; to provide information on the long term stress and deformation behaviour of the mine pillars before and after backfilling; to provide information on the long term load and deformation behaviour of the backfill; to provide information on the long term effectiveness of the grout/backfill system as a brine control technique; to provide information on the long term stress and deformation characteristics of the Dawson Bay before and after backfilling.

The selected instruments for Panel 209 included convergence meters for the rooms, earth pressure cells and piezometers for the backfill, extensometers and borehole pressure cells for the host salt and potash formations, and stressmeters and strain gauges for the Dawson Bay Formation. The technical specifications of each of the selected instruments are presented in Appendix C. A cross section showing the dis-

tribution of these instruments and their role to provide the most complete information on the strata behaviour in Panel 209 is presented in Figure 15. In plan view, these instruments were arranged as shown schematically in Figure 16. In this figure, two full instrumentation stations, one pillar instrumentation station, four secondary instrumentation stations and two borehole instrumentation stations form the data gathering system established for Panel 209. The identification of each instrument and their location in mine coordinates are presented in Appendix D. Each of these instrumentation stations are discussed in detail in the following subsections.

5.5.1 THE FULL INSTRUMENTATION STATIONS

Two full instrumentation stations were designed to give the complete information on the long term stress and deformation response of the backfill and surrounding strata. One station is located in W54N between N6 and N7 and the second station will be located in W54N8E. Each instrumentation station is composed of one convergence meter, two borehole extensometers, one earth pressure cell and one piezometer, as illustrated in Figure 17.

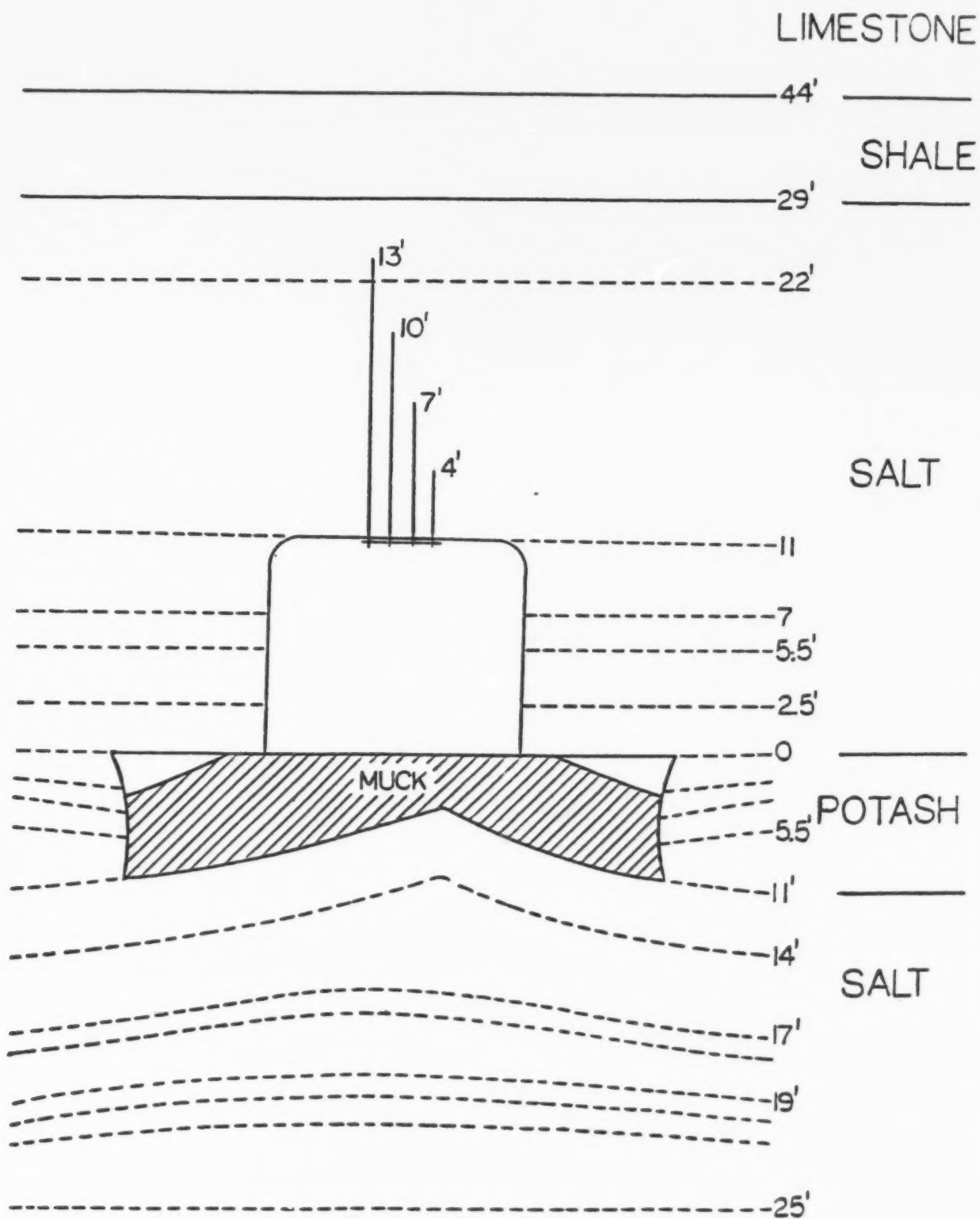
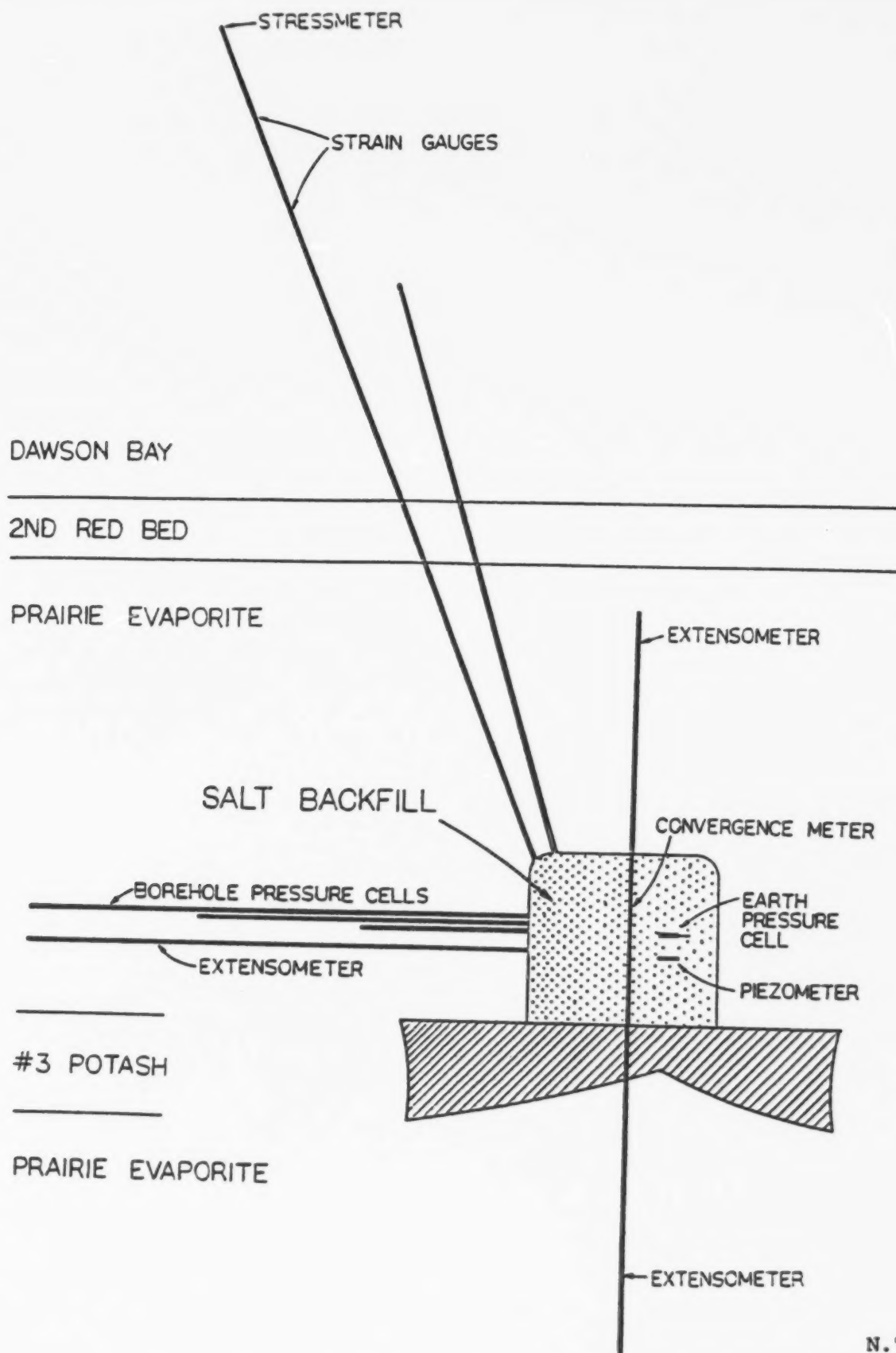


Figure 14. DEEP PIN STATION - PANEL 209

1ST RED BED



N.T.S.

Figure 15. A TYPICAL INSTRUMENTATION CROSS SECTION FOR
PANEL 209

-
- CONVERGENCE METER
 ■ BACK EXTENSOMETER
 ◻ FLOOR EXTENSOMETER
 ▲ PILLAR EXTENSOMETER
 ○ EARTH PRESSURE CELL
 ● BOREHOLE PRESS. CELL
 — STRAIN GAUGE
 • STRESSMETER
 = PIEZOMETER
- W54N, W53N, N7, N5, N11, N13
- N.T.S.

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Figure 16. THE INSTRUMENTATION PROGRAM IN PANEL 209

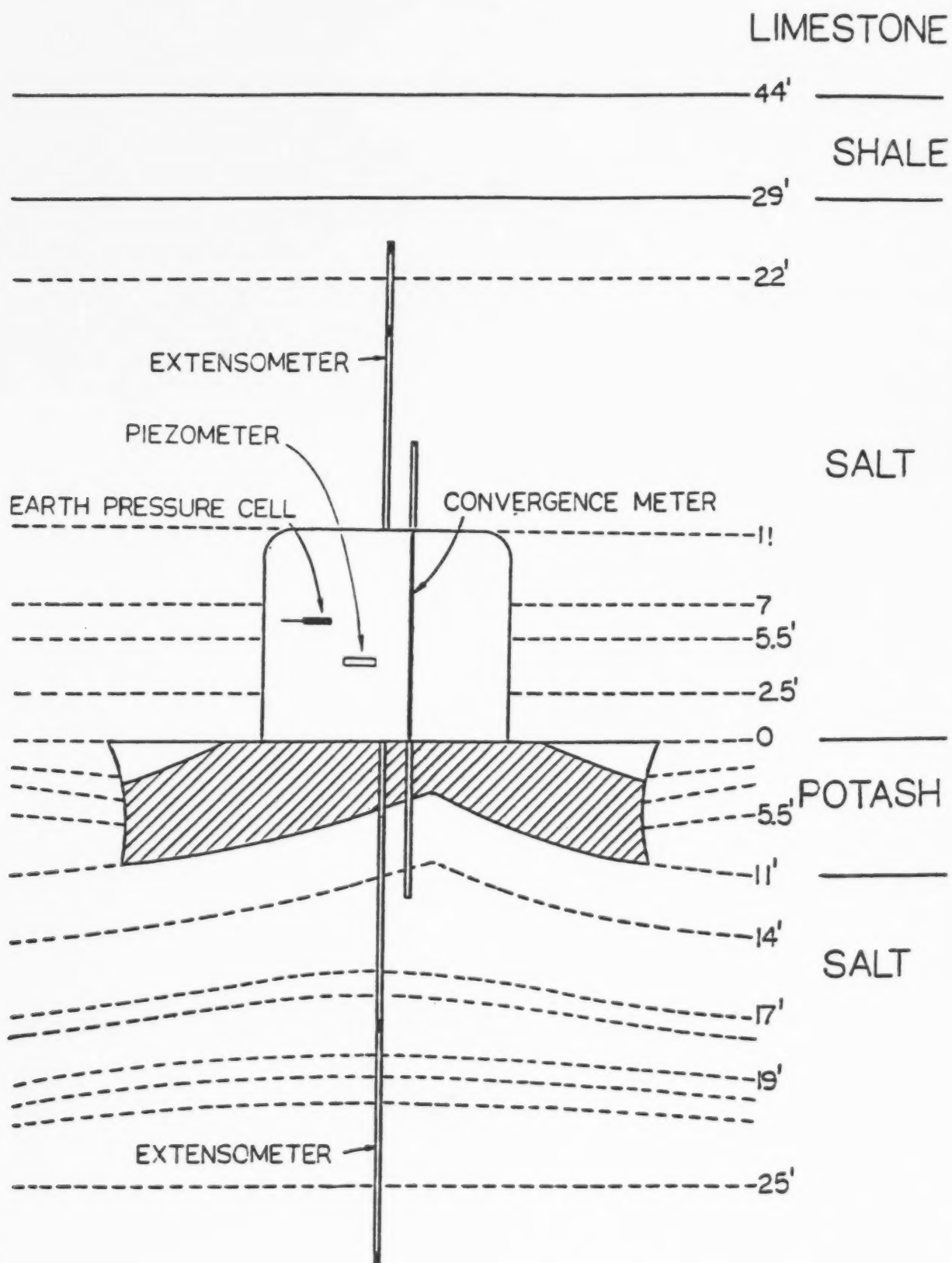


Figure 17. THE FULL INSTRUMENTATION STATION DESIGN FOR
PANEL 209

The convergence meter was installed from roof to floor in the rooms. It was designed to provide information on the room closure in the panel, thus establishing the data for verifying the effectiveness of the placement of the backfill and for verifying its long term control on ground closure.

The roof extensometer is a two anchor rod extensometer, installed in the host salt formation. The anchors were established at depths 3 metres (10 feet) and 4.9 metres (16 feet) above the mine back. The floor extensometer is also a two anchor rod extensometer and the anchors were established at 5.8 metres (19 feet) and 9.1 metres (30 feet) below the floor. These extensometers were designed to monitor clay seam separation and to establish the deformation behaviour of the host salt before and after backfilling. The convergence meter and extensometers will provide the necessary information to study the interaction between the salt formation and the backfill in terms of reduction of room closure and ground subsidence.

The earth pressure cell was designed to monitor the change in total pressure in the backfill, thus establishing its loading conditions and bearing capability. The piezometer will provide information on the flow path of brine through the backfill, also establishing the in situ permeability of the fill system.

5.5.2 THE PILLAR INSTRUMENTATION STATION

One pillar instrumentation station was established in W54N7W in Panel 209 to monitor the long term load/deformation characteristics of the abutment pillars before and after backfilling. This station is composed of three borehole pressure cells and one horizontal extensometer, as illustrated in Figure 18.

The borehole pressure cells were installed at 15.2, 30.5 and 45.7 metres (50, 100 and 150 feet) away from the panel boundary. They were designed to establish the load differential with depth in the pillars and the long term stress changes in the pillar area before and after backfilling.

The horizontal extensometer is a three anchor rod extensometer, the anchors being established at the same depths as the borehole pressure cells. The extensometer was designed to establish the long term deformation characteristics of the barrier pillar, before and after backfilling.

The effects of the stress variation on the deformation of the pillar is defined by combining data from both the borehole pressure cells and horizontal extensometer.

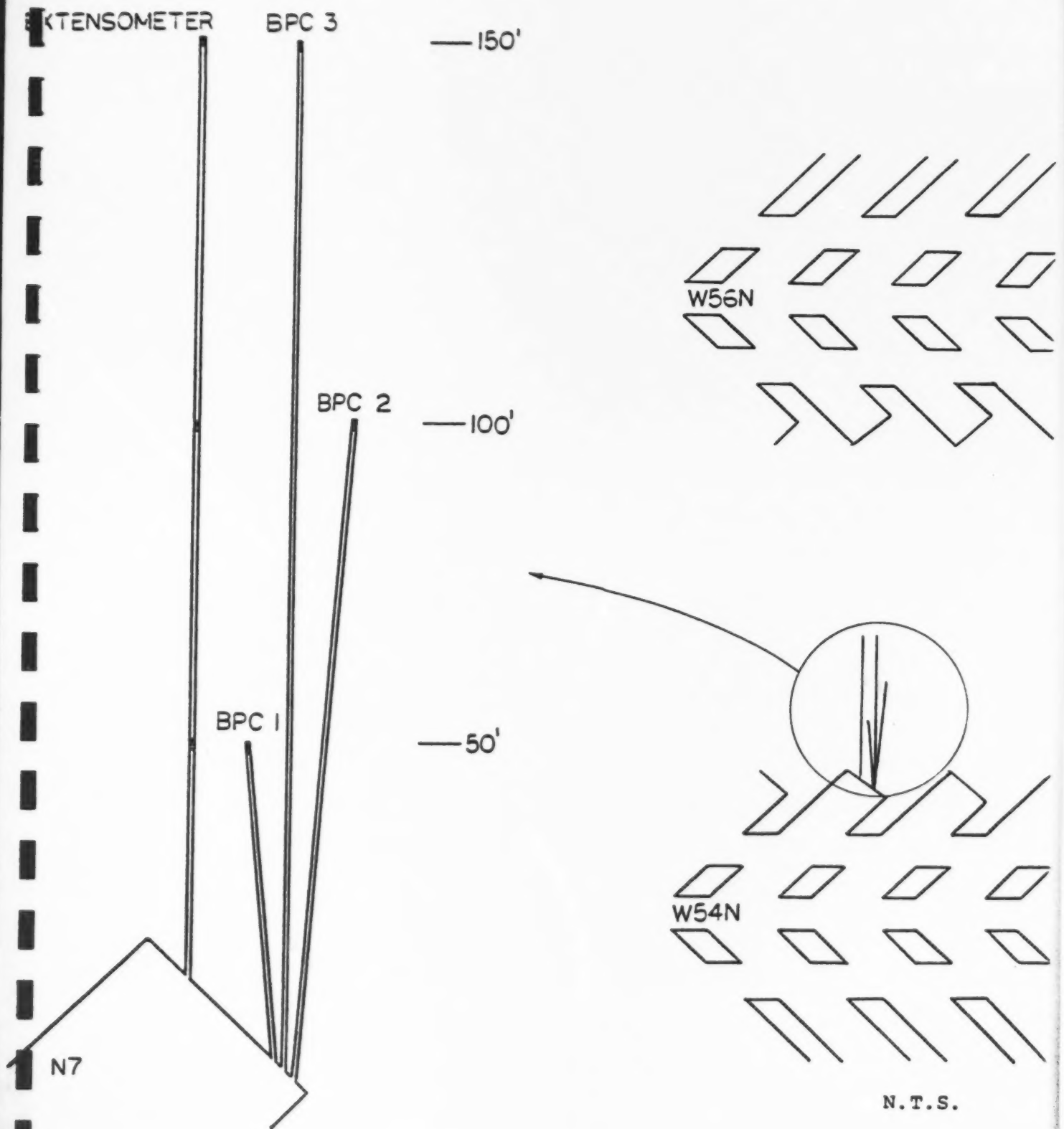


Figure 18. THE PILLAR INSTRUMENTATION STATION DESIGN FOR
PANEL 209

5.5.3 THE SECONDARY INSTRUMENTATION STATIONS

Four secondary instrumentation stations were established in Panel 209. Two stations were established in W54N, one between N7 and N8 and the other in N11, and two stations were established in W53N, one between N7 and N9 and one in N9. The stations are composed of earth pressure cells and piezometers.

The earth pressure cells were designed to monitor the change in total pressure in the backfill, thus establishing its loading conditions and bearing capability. The earth pressure cells were located close to and away from the area of inflow, to study the influence of brine on the backfill loading capability.

The piezometers were distributed along W53N and W54N to provide a complete coverage of brine movement in Panel 209. The piezometers will thus provide information on the brine flow pattern through the backfill, also establishing the in situ permeability of the fill system.

5.5.4 THE BOREHOLE INSTRUMENTATION STATIONS

Two borehole instrumentation stations were designed to provide information on the long term stress and deformation characteristics of the Dawson Bay before and after backfilling. They were established in two of the exploratory grout holes in Panel 209, one located in N5 and the other in N8. The stations are composed of stressmeters and strain gauges, as illustrated in Figure 19. The stressmeters will provide information on the loading characteristics of the Dawson Bay Formation and the strain gauges will determine the deformations associated with the changes in stress.

The stations were located at different depths in the limestone, one above and the other below the neutral axis of the Dawson Bay Formation. They were designed to establish the structural behaviour of the formation, thus defining if it behaves as a beam, a plate or as any other engineering structure. An understanding of the long term behaviour of the Dawson Bay Formation as associated with mine closure and ground subsidence will also be established.

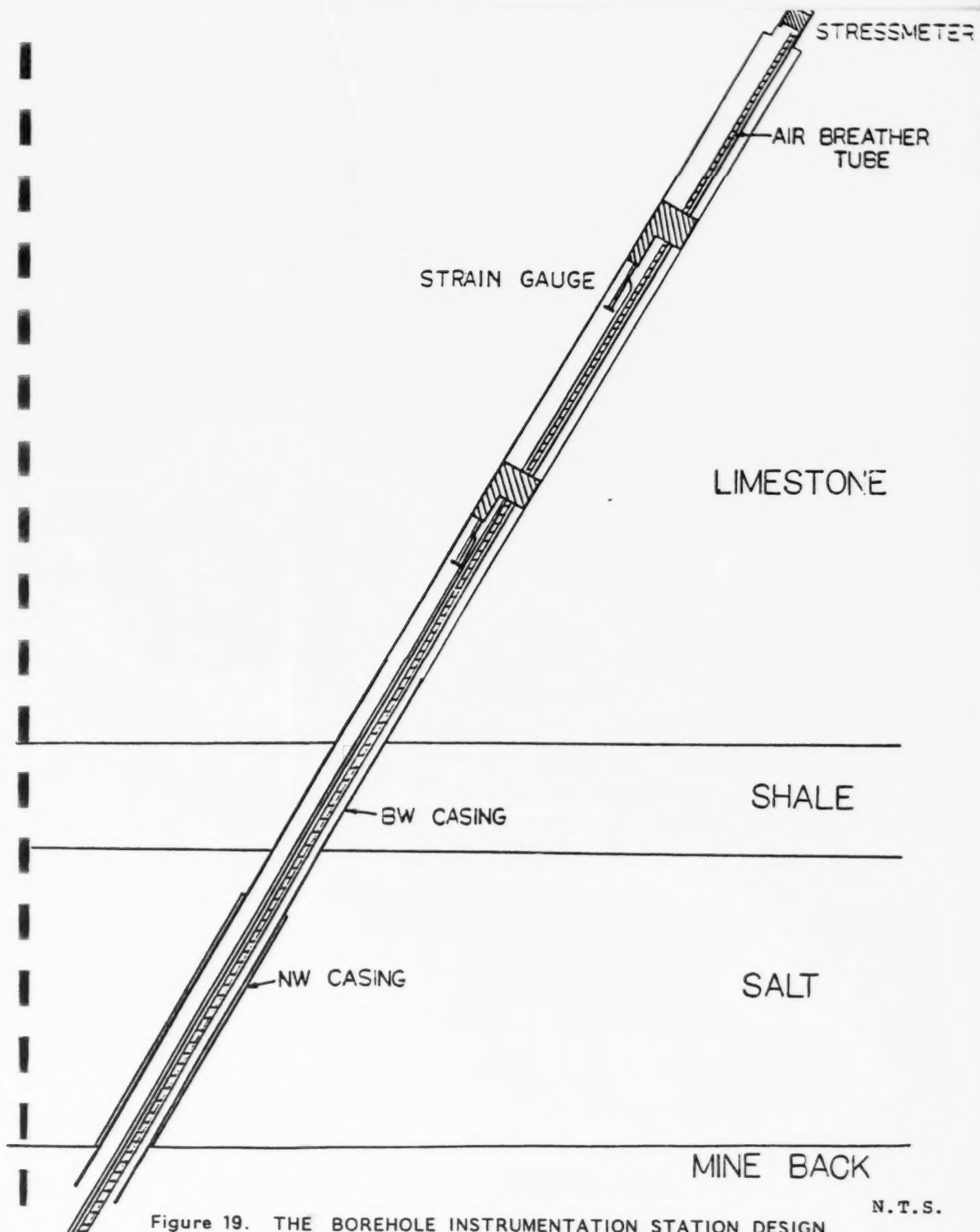


Figure 19. THE BOREHOLE INSTRUMENTATION STATION DESIGN
FOR PANEL 209

5.6 THE DATA ACQUISITION SYSTEM FOR PANEL 209

All the instruments installed in Panel 209 were connected to a data acquisition system, specially designed to receive and store the transmitted instrument data. The data acquisition system consists of a data logging system and an Otrona Attache host computer. Approximately 4600 metres (15100 feet) of cable was used for the connections between the instruments and the microprocessor, and a total of 84 wires were fed to the data acquisition system.

The datalogger contains a digital board with 16 channels for connecting the vibrating wire units and an analog board with 16 channels for connecting the analog voltage type displacement transducers. Software is used for taking the readings automatically at user defined time intervals and the transmitted data is stored on a disk. Simplified wiring diagrams showing the gauge connections appear in Appendix D.

6 THE RESEARCH WORK IN PANEL 109

6.1 REVIEW OF PREVIOUS WORK

Once the brine inflow was encountered in Panel 109 in 1974, extensive timber cribbing and posting was undertaken to provide support to the area. Deteriorating ground conditions and an increase in inflow rate resulted in the construction of one test reinforced concrete bulkhead in the area. It was not successful and others were not put in place. A pumping program was also undertaken to pump brine out of the inflow area.

The continuous increase in inflow led to the decision to attempt to grout off the inflow area. The grouting program was done by late 1975, when the inflow had reached 105 lpm (23 lgpm). It consisted of injecting flyash and concrete grout into the Prairie Evaporite. When the brine pressured up it broke out of the salt in other locations. The grouting program showed limited success. Brine leakage further developed in other areas of the panel slightly increasing the inflow to 82 lpm (18 lgpm) and the grouting program was halted in the beginning of 1976. During the following years the rate fluctuated widely but has decreased to a rate

of 14 lpm (3 lgpm). A graph showing the variation of brine flow with time is presented in Figure 6.

Since the occurrence of the inflow a monitoring program in terms of room closure and brine inflow was established. Brine chemistry, specific gravity, pH level, temperature, pressure and flow were constantly monitored. Brine quality has not changed markedly over the years. Typical brine chemical test results are presented in Figure 5.

Closure rates in the order of 1.8 cm/100 days (0.7 inches/100 days) have characterized the ground movement in the area. This is normal steady state closure rates for Block 1. Much of the support previously installed has failed and the accessible areas have an effective height of approximately 1.2 m (4 feet).

6.2 REHABILITATION OF ACCESSWAYS TO PANEL 109

A safe and well ventilated passage to Panel 109 was successfully developed through an extensive rehabilitation program of more than 2900 metres (9500 feet) of access drifts. The rehabilitated accessways to Panel 109 are shown in Figure 1. The work was undertaken to control the

effects of stress, ground closure, floor heaves and pillar slabbing to provide a safe passage.

The rehabilitation work was done by the Voest Alpine miner AM50 and two to four 3.8 cu.m. (5 cubic yards) scooptrams. The large haulage fleet was necessary because of the long haulage distances involved. Muck storage was a constant problem as room closure in Block I has effectively closed off nearby mined out panels.

The rehabilitation work involved similar procedures as described for Panel 209 (Section 5.2). Only minor ground support was necessary in localized unstable areas and visual inspection and manual scaling were done on a daily basis.

6.3 REHABILITATION WORK IN PANEL 109

The rehabilitation work was necessary to provide access because the panel is inaccessible for the grouting and backfilling operations due to ground closure. The rehabilitation work in Panel 109 involved three steps as shown in Figure 20. Approximately 457 meters (1500 feet) of access into the test area were developed. With the rehabilitation work complete,

the grouting, instrumentation and backfilling programs will be carried out.

6.4 THE GROUTING PROGRAM IN PANEL 109

Four holes were initially drilled and tested (84-2 to 84-5, in Figure 21). Flow and dye tests have indicated that there is a decreasing pressure gradient in an east to west direction (the holes were all to the east of the brine inflow location). Further drilling and testing is planned and will provide means for more general conclusions on the brine flow characteristics. A drill hole layout was designed (shown in Figure 21 (holes 1-6)) to form a curtain of grout around the inflow. Once the drilling is complete, the formation pressure and flow characteristics can be determined.

The grouting program will follow the same sequence as Panel 209. A cement grout will be used in primary holes followed by chemical grout in the secondary holes.

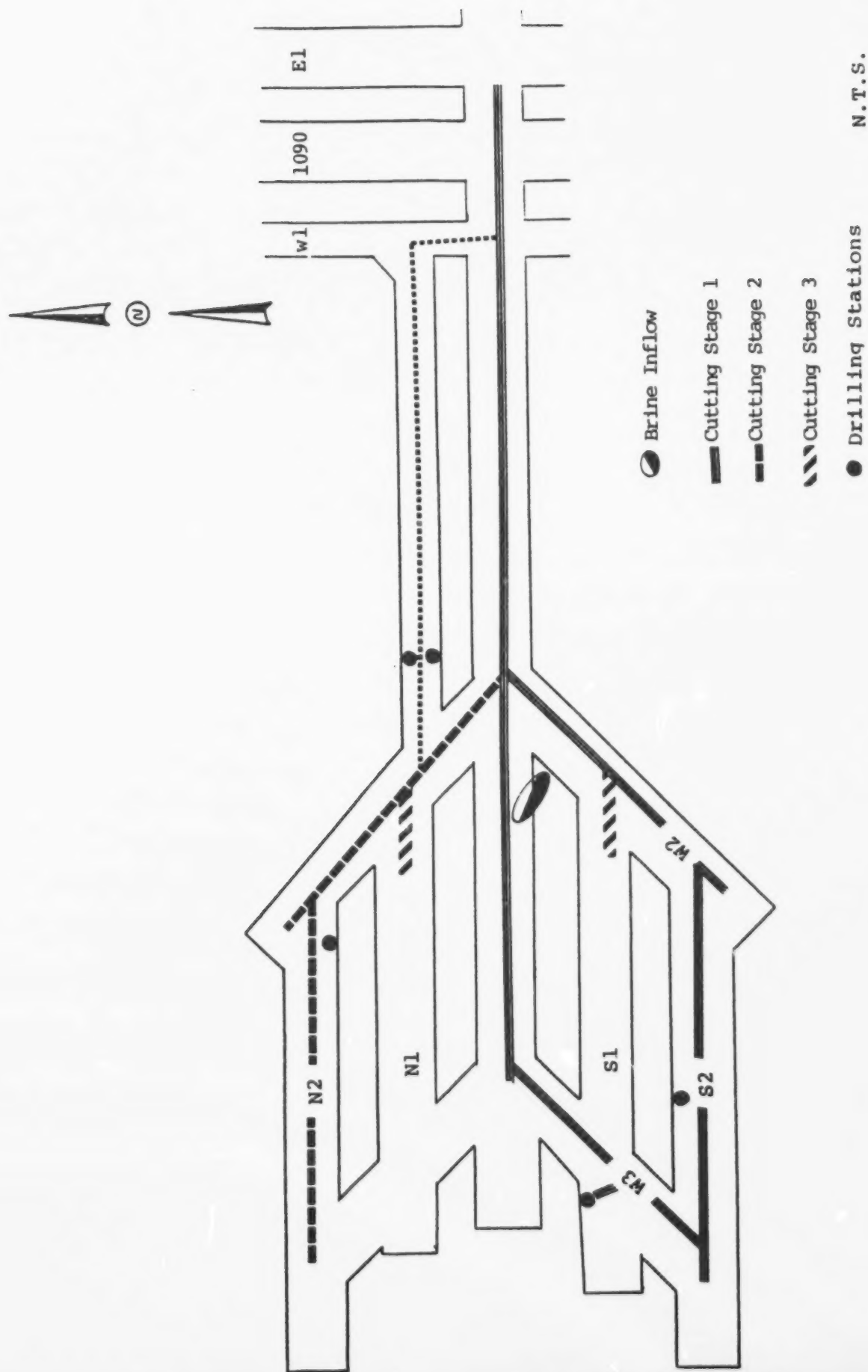
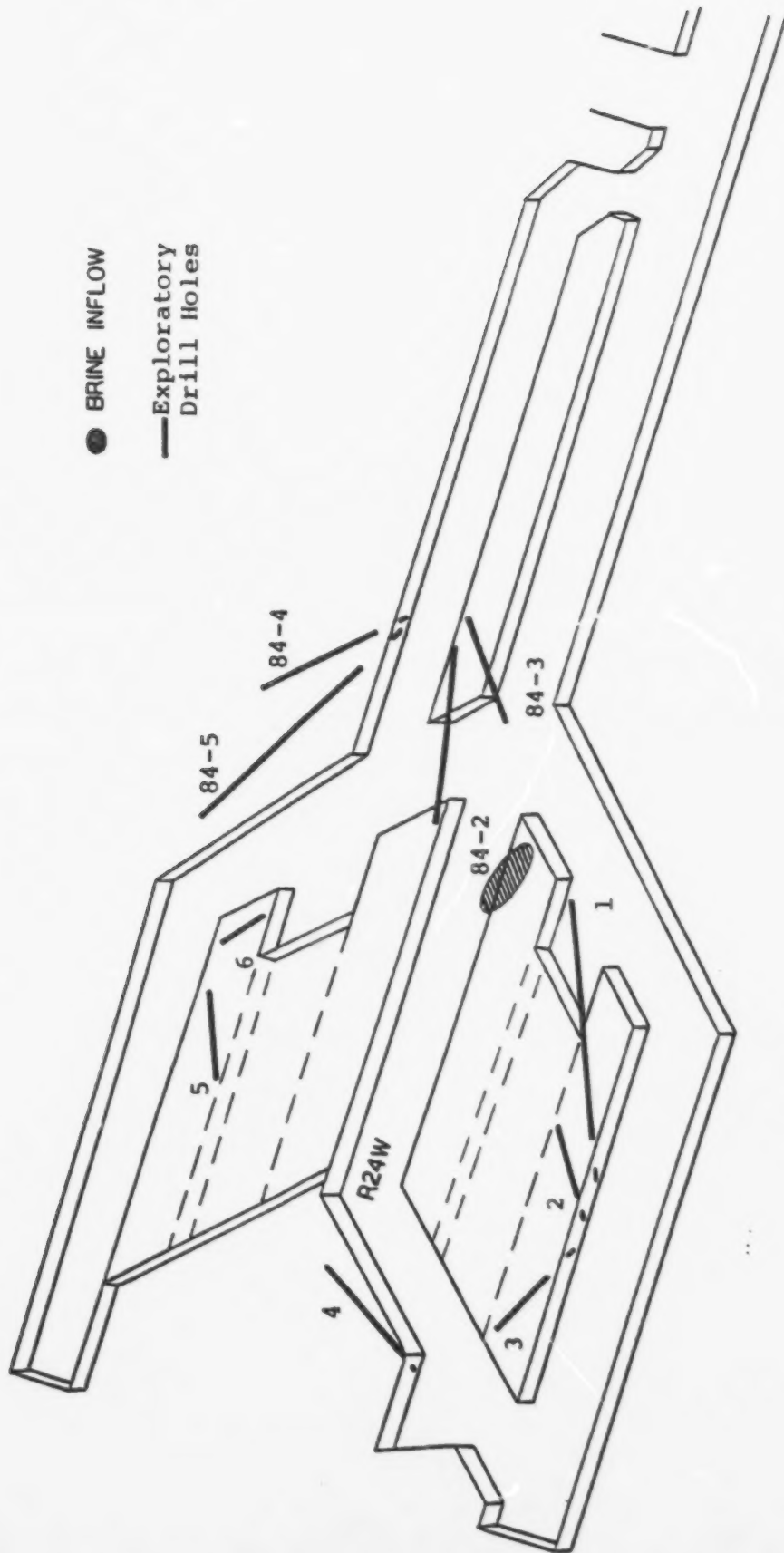


Figure 20. REHABILITATION OF ACCESS INTO PANEL 109



N.T.S.

Figure 21. THE EXPLORATORY DRILL HOLE LAYOUT IN PANEL 109

6.5 THE INSTRUMENTATION PROGRAM IN PANEL 109

The instrumentation program was designed to achieve the same objectives in Panel 109 as was laid out for Panel 209.

The first part of the instrumentation program in Panel 109 involves the gathering of information from previous studies undertaken in the area, including geophysical evaluations, geologic maps and exploration drill logs. A series of structural and stratigraphic cross sections have been constructed to indicate the specific geology of the mine area in Panel 109. The additional information from exploratory holes served to explain the structure and conditions encountered in the area. The depths of the formation contacts and the clay seam configuration occurring in the area were determined. A simplified structural cross section for Panel 109 showing the formation thicknesses and the clay seam configurations is presented in Figure 22. The depths shown are related to the back elevation in the old mine workings.

The instrumentation program was designed based on the findings to date. It was designed to provide the most detailed information about the interaction of the backfill with the surrounding formations, and to provide information on how to predict and control the deformation behaviour of the strata in the area.

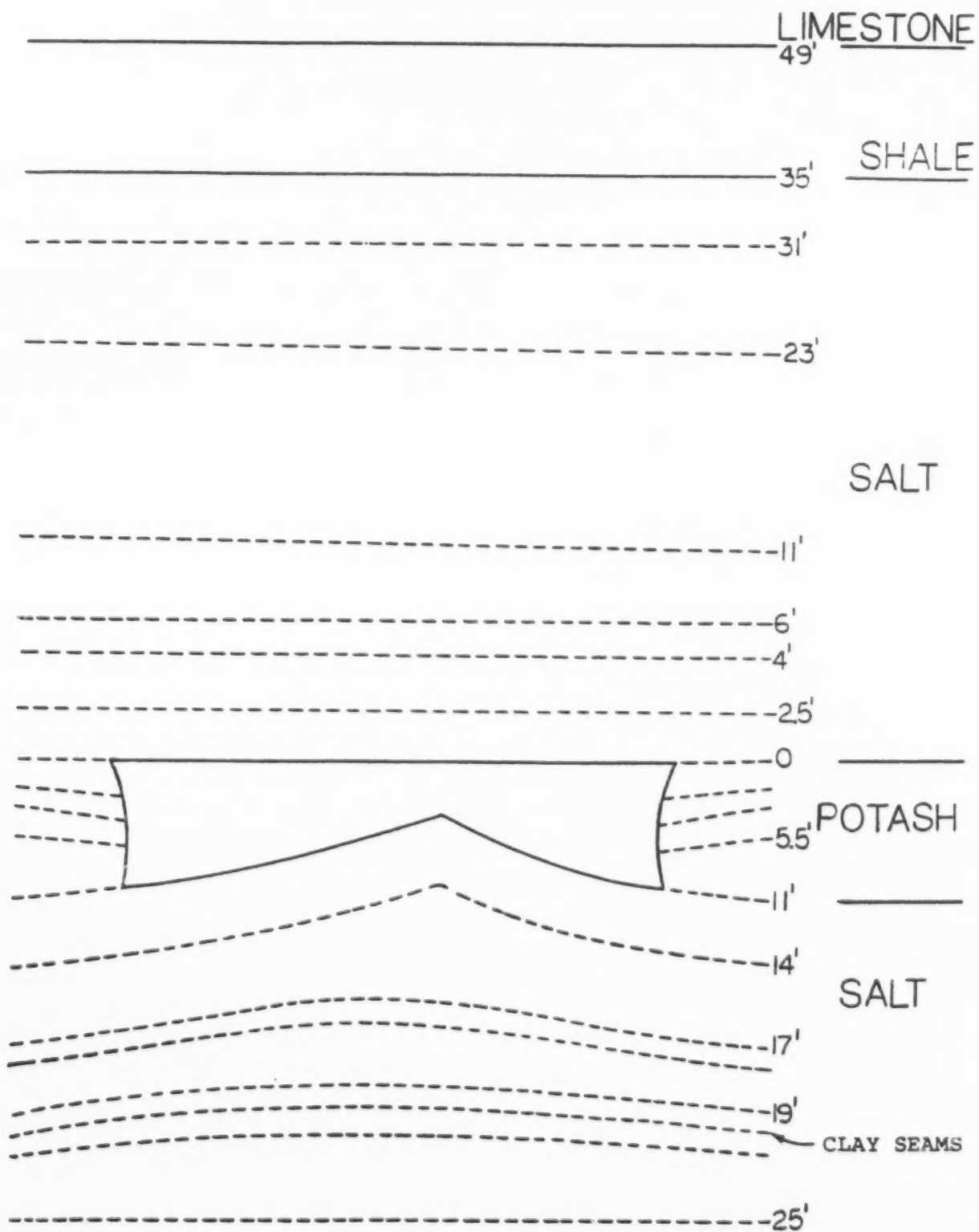


Figure 22. SIMPLIFIED STRUCTURAL CROSS SECTION - PANEL 109

A series of temporary and permanent instrumentation stations were designed in order to monitor the stress changes and related closures in the backfill and surrounding strata. The temporary stations consisted of room closure pin stations and deep pin stations. They were used to pick up closure prior to the installation of the permanent instrumentation stations. Two room closure pin stations and one deep pin station were installed in Panel 109. The location of these stations is shown in Figure 23.

The room closure pin stations consisted of 3 or 5 hilti pins installed on the roof and walls of the opening. A tape extensometer was used for reading the vertical and horizontal changes in dimension of the rooms. These stations have established vertical and horizontal closure rates in Panel 109 averaging 0.86 cm/100 days (0.34 inches/100 days) and 1.14 cm/100 days (0.45 inches/100days), respectively. Typical curves of vertical and horizontal closures with time are presented in Figure 24. These stations will also be used to monitor possible ground instabilities which may be induced when the grouting program is initiated.

The deep pin station consisted of two mechanical bolts anchored at different depths in the salt back. This station is being used to monitor clay seam separation and ground instability in the vicinity of drill stations. It has indicated no clay seam separation or ground instability to date.

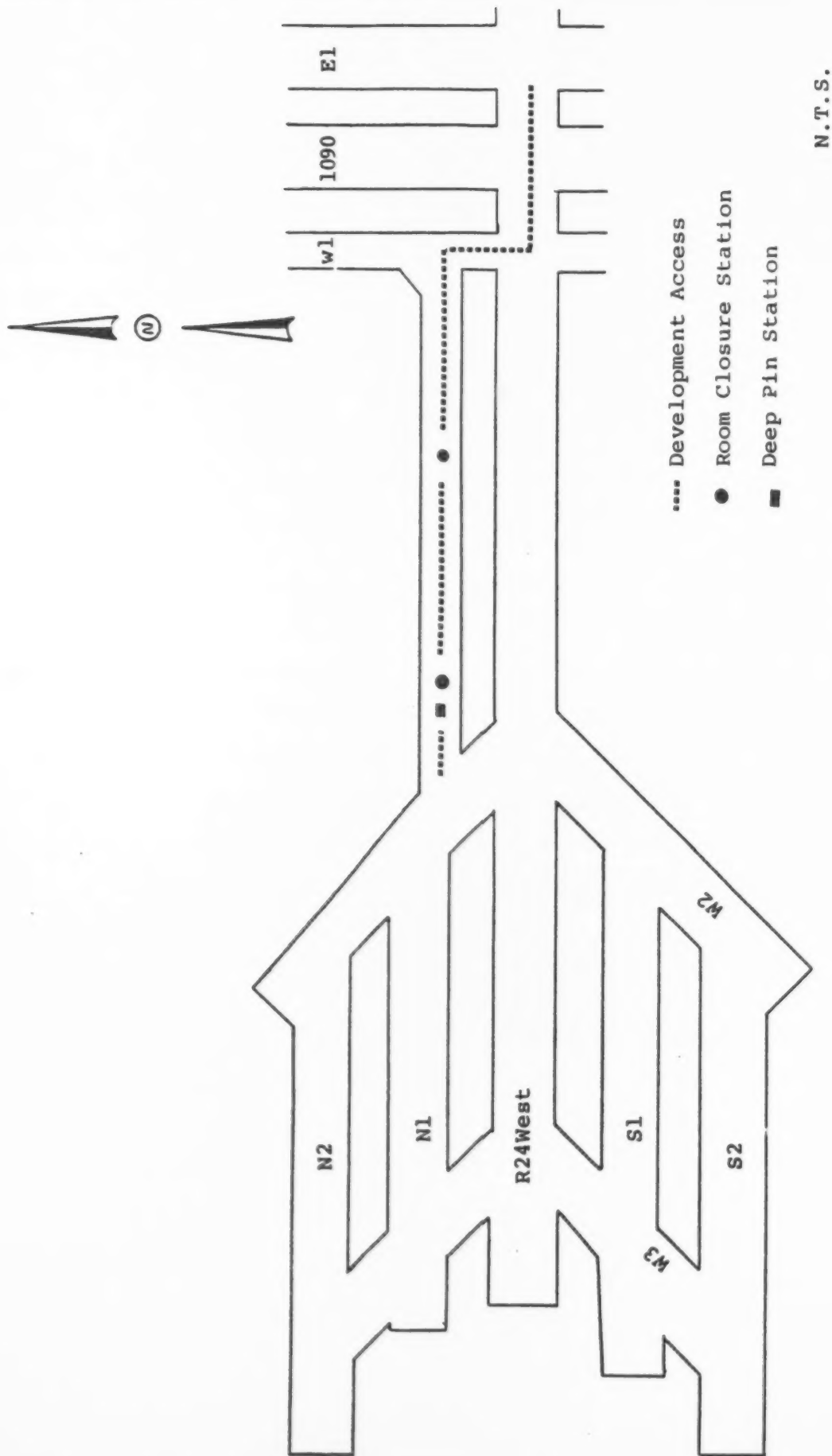


Figure 23. TEMPORARY INSTRUMENTATION STATION LAYOUT -
PANEL 109

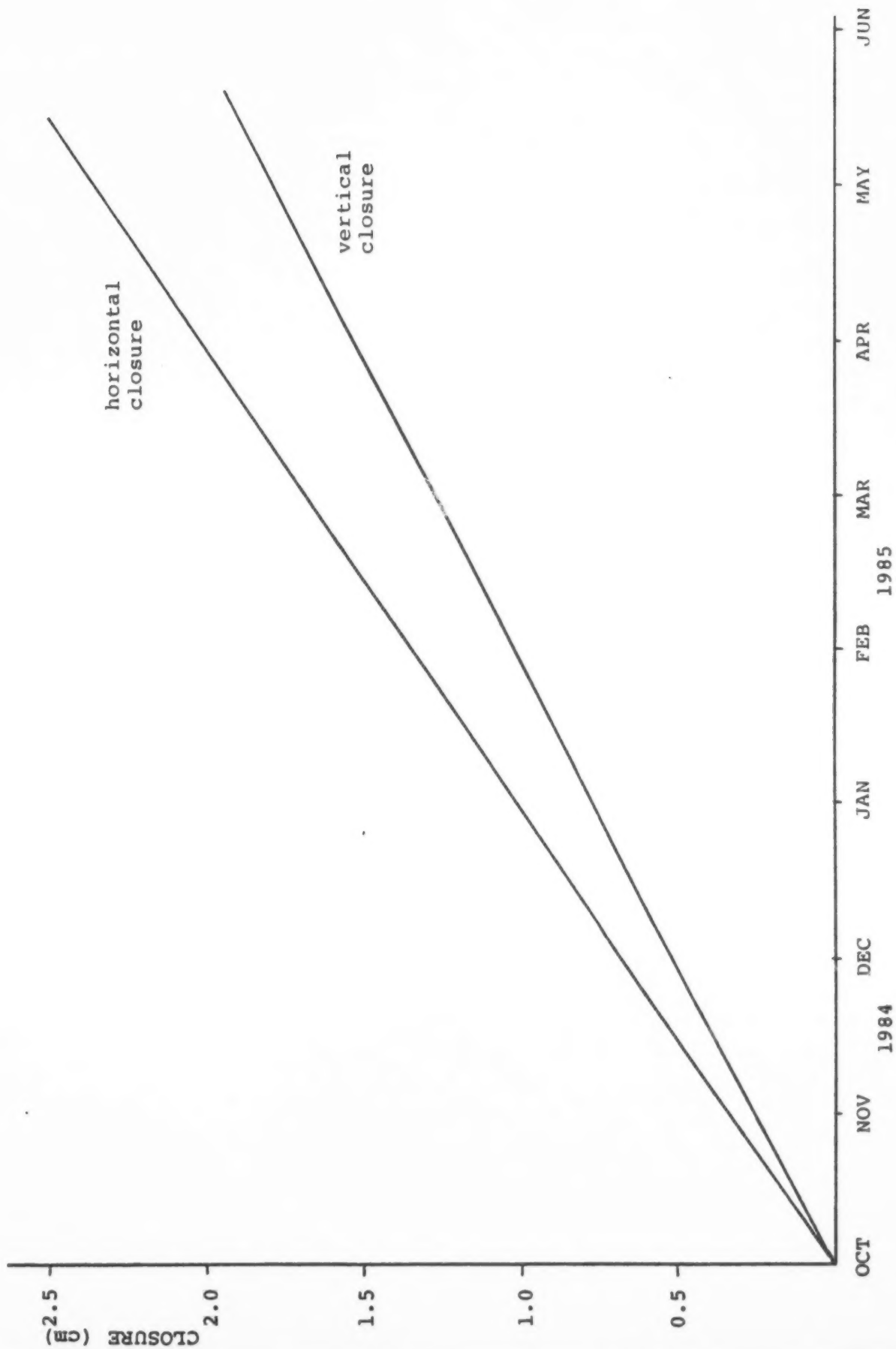


Figure 24. ROOM CLOSURE VS TIME - PANEL 109

The permanent instrumentation stations were designed to study the interaction of the backfill with the surrounding strata. They were designed to perform similar tasks to the stations established in Panel 209 (see section 5.5). The selected instruments for Panel 109 included convergence meters for the rooms, earth pressure cells and piezometers for the backfill, extensometers for the host salt formation, and stressmeters and strain gauges for the Dawson Bay Formation. The technical specifications of each of the selected instruments are presented in Appendix C. A plan showing the distribution of these instruments in Panel 109 is presented in Figure 25. In this figure, one full instrumentation station, one secondary instrumentation station and two borehole instrumentation stations form the data gathering system established for Panel 109. The identification of each instrument and their location in mine coordinates are presented in Appendix E. Each of these instrumentation stations are discussed in detail in the following sub-sections.

6.5.1 THE FULL INSTRUMENTATION STATION

One full instrumentation station was designed to give the complete information on the long term stress and deformation response of the backfill and surrounding strata and is located close to the inflow location. The instrumentation station is composed of one convergence meter, two

borehole extensometers, one earth pressure cell and one piezometer, as illustrated in Figure 25.

The convergence meter will be installed from roof to floor in the room. It was designed to provide information on the room closure in the center of the panel and verify the effectiveness of the backfill and its long term control on ground closure.

The roof extensometer is a two anchor rod extensometer, installed in the host salt formation. The anchors were established at depths 4.9 metres (16 feet) and 6.7 metres (22 feet) above the mine back. The floor extensometer is also a two anchor rod extensometer and the anchors were established at depths 5.8 metres (19 feet) and 9.1 metres (30 feet) below the mine floor. These extensometers were designed to monitor clay seam separation and to establish the deformation behaviour of the host salt before and after backfilling.

The convergence meter and extensometers will provide the necessary information to study the interaction between the salt formation and the backfill in terms of reduction of room closure and ground subsidence.

The earth pressure cell was designed to monitor the change in total pressure in the backfill, thus establishing its loading conditions and bearing capability. The piezometer will provide information on the flow

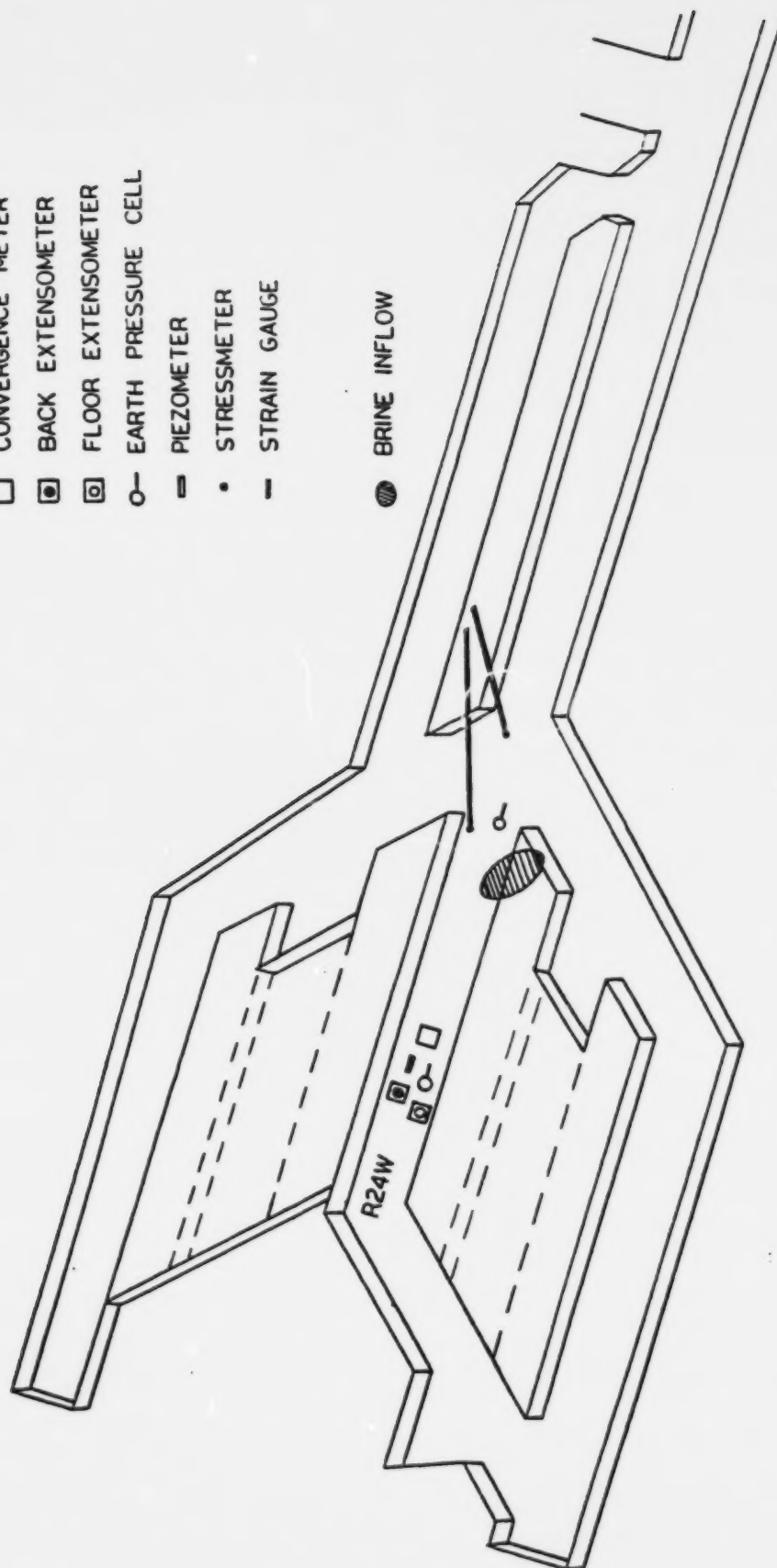
path of brine through the backfill, also establishing the in situ permeability of the fill system.

6.5.2 THE SECONDARY INSTRUMENTATION STATION

One secondary instrumentation station will be established at the intersection between R24W and wing W2. It is composed of one earth pressure cell (Figure 25). The earth pressure cell will be located away from the inflow location. The earth pressure cell was designed to monitor changes in total pressure in the backfill, thus establishing its loading conditions and bearing capability.

The secondary station is located underneath the projected borehole instrumentation stations and will serve to associate the changes in load in the backfill with changes in stress in the Dawson Bay Formation.

- CONVERGENCE METER
- ▣ BACK EXTENSOMETER
- ▢ FLOOR EXTENSOMETER
- EARTH PRESSURE CELL
- PIEZOMETER
- STRESSMETER
- STRAIN GAUGE
- BRINE INFLOW



N.T.S.

Figure 25. THE INSTRUMENTATION PROGRAM IN PANEL 109

6.5.3 THE BOREHOLE INSTRUMENTATION STATIONS

Two borehole instrumentation stations were established in exploratory grout holes, as shown in figure 25. They are composed of stressmeters and strain gauges. The stations were located at different depths in the limestone, one above and the other below the neutral axis of the Dawson Bay Formation.

The instrumentation will provide information on the long term stress and deformation characteristics of the Dawson Bay before and after backfilling. The stressmeters will provide information on the loading characteristics of the Dawson Bay Formation and the strain gauges will determine the deformations associated with the changes in stress.

6.6 THE DATA ACQUISITION SYSTEM FOR PANEL 109

All the instruments installed in Panel 109 will be connected to a manual reading station, specially designed to receive the transmitted instrument data. The manual reading station consists of a 12 channel switch box an excitation unit, a voltmeter and a vibrating wire readout box. Approximately 1050 metres (3450 feet) of cable will be used for the

connections between the instruments and the reading station, and a total of 30 wires will be fed to the data collection system.

The switch box contains 12 channels for connecting both the vibrating wire units and the analog voltage type displacement transducers. The readout box is a Geokon model GK-401 and is used for taking the vibrating wire readings. The voltmeter is used for reading the analog units. All the readings are taken manually.

Simplified wiring diagrams showing the gauge connections are presented in Appendix E.

7 THE SALT BACKFILLING PROGRAM

7.1 INTRODUCTION

The progressive closure and deformation of the overlying formations due to subsidence, if not controlled, may result in renewed leakage into the mine. With proper control of closure, no disturbance in the water bearing formations should occur. Failure of the Dawson Bay Formation should not occur and no new cracks should open up. The grout curtain, established in the grouting program, should remain intact and its effectiveness should be assured.

Salt backfilling is, in this case, the best mechanism for ground stabilization in the test areas, assuming an effective control of the inflows. A series of backfilling techniques were analysed and pneumatic stowing was selected as the best alternative. Pneumatic stowing offers maximum backfill compaction in the mine openings and good backfilling to the back (see Figure 26). Scoop trams will be used to feed the stowing system with the waste salt.

The following list of items represents the components of the system:
crushing unit (100 TPH capacity), transfer conveyor (hydraulic power)

which transports the fill material from the crusher to a surge hopper, surge hopper (3,8 cu.m. capacity) with scalper to receive the crushed material, conveyor which transports the fill material from the surge hopper to the stowing unit, motor and blower assembly which will provide approximately 5000 CFM, using a 250 H.P. electric motor, pneumatic stower, control console, discharge line to convey the backfill to the selected areas, and discharge nozzle to direct and discharge the backfill during placement.

Closure in most of the openings in the areas have reached 60-70% the original height; access for backfilling those areas will be incomplete.

Laboratory tests are being performed to investigate some of the relevant variables involved with the backfilling operation: material composition, size analysis, density, porosity, permeability, moisture content, strength, etc. The laboratory testing program is presented in appendix B.

The long term data would be analysed using numerical techniques so that the geomechanical behaviour of the backfill can be modelled.

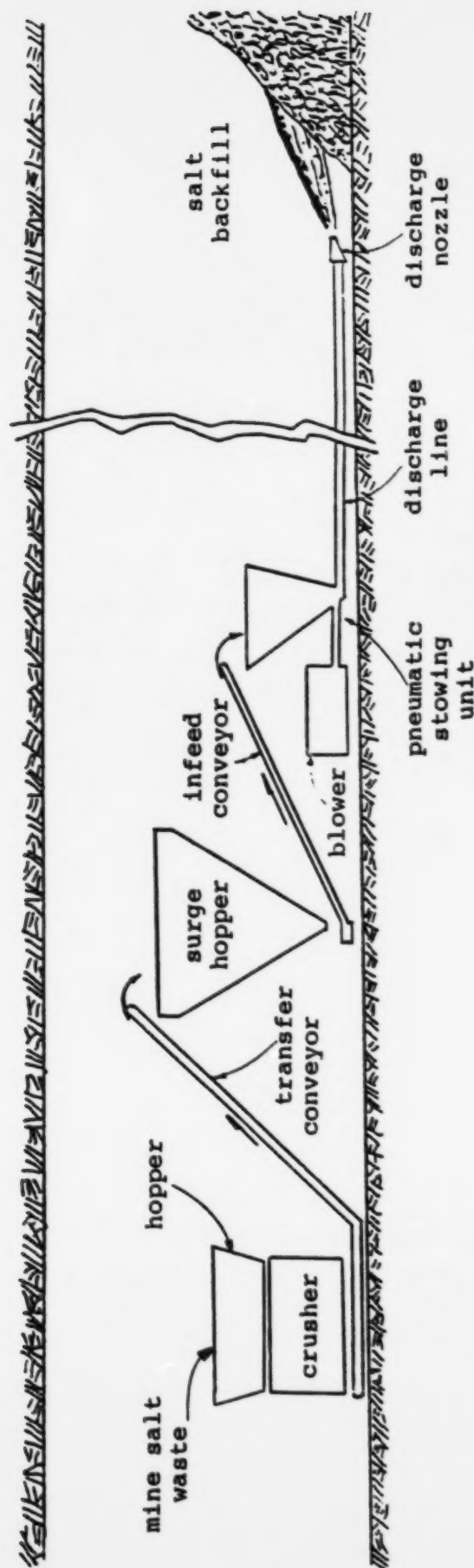


Figure 26. THE BACKFILLING METHOD FOR PANELS 109 AND 209

7.2 THE BACKFILLING OPERATION IN PANEL 209

The backfilling in panel 209 will take place in the delineated zone in figure 27.

The backfilling operation in Panel 209 will involve the following steps:

- 1 - The backfilling equipment is set up between W53N and W54N in N43W,

- 2 - Backfilling starts in W54N as the AM50 supplies muck from N43W as it cuts eastward,

- 3 - Once the backfilling operation is complete in W54N the backfilling equipment is moved to the station in W53N/N43W,

- 4 - W53N is backfilled.

Approximately 20000 tonnes (22000 tons) of waste salt will be required to backfill Panel 209. Instrumentation of the backfill will be performed during the backfilling operation, as discussed before.

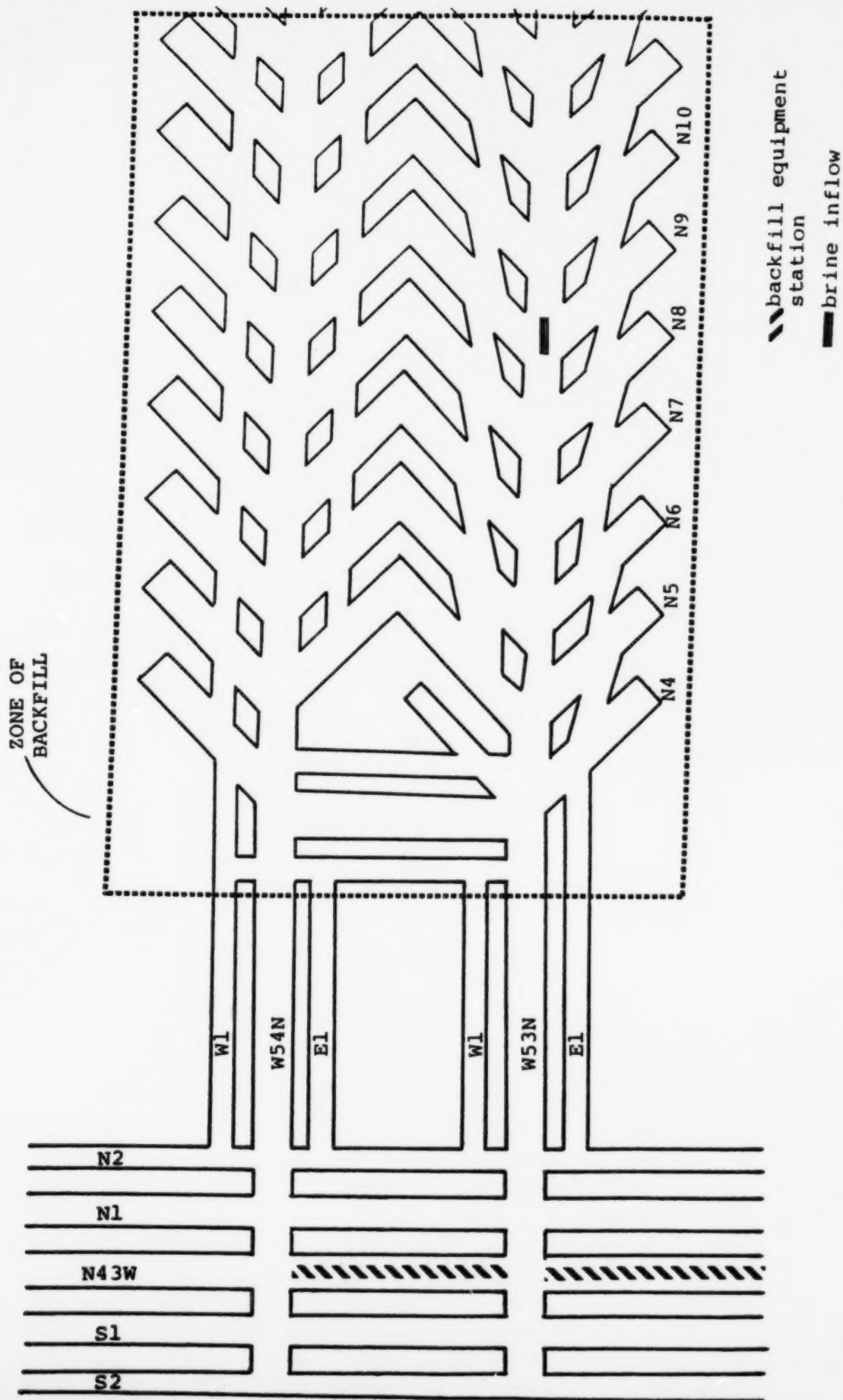


Figure 27. THE BACKFILLING PROGRAM FOR PANEL 209

7.3 THE BACKFILLING OPERATION IN PANEL 109

The backfilling in panel 109 will take place in the delineated zone in figure 28. Salt muck for backfilling will be supplied by the AM50. The backfilling equipment will be set up in 1090 and the salt waste will be transported to this station using scoop trams. The procedures developed during the backfilling of Panel 209 will be used in this test area. Approximately 10000 tonnes (11000 tons) of waste salt will be required to backfill Panel 109.

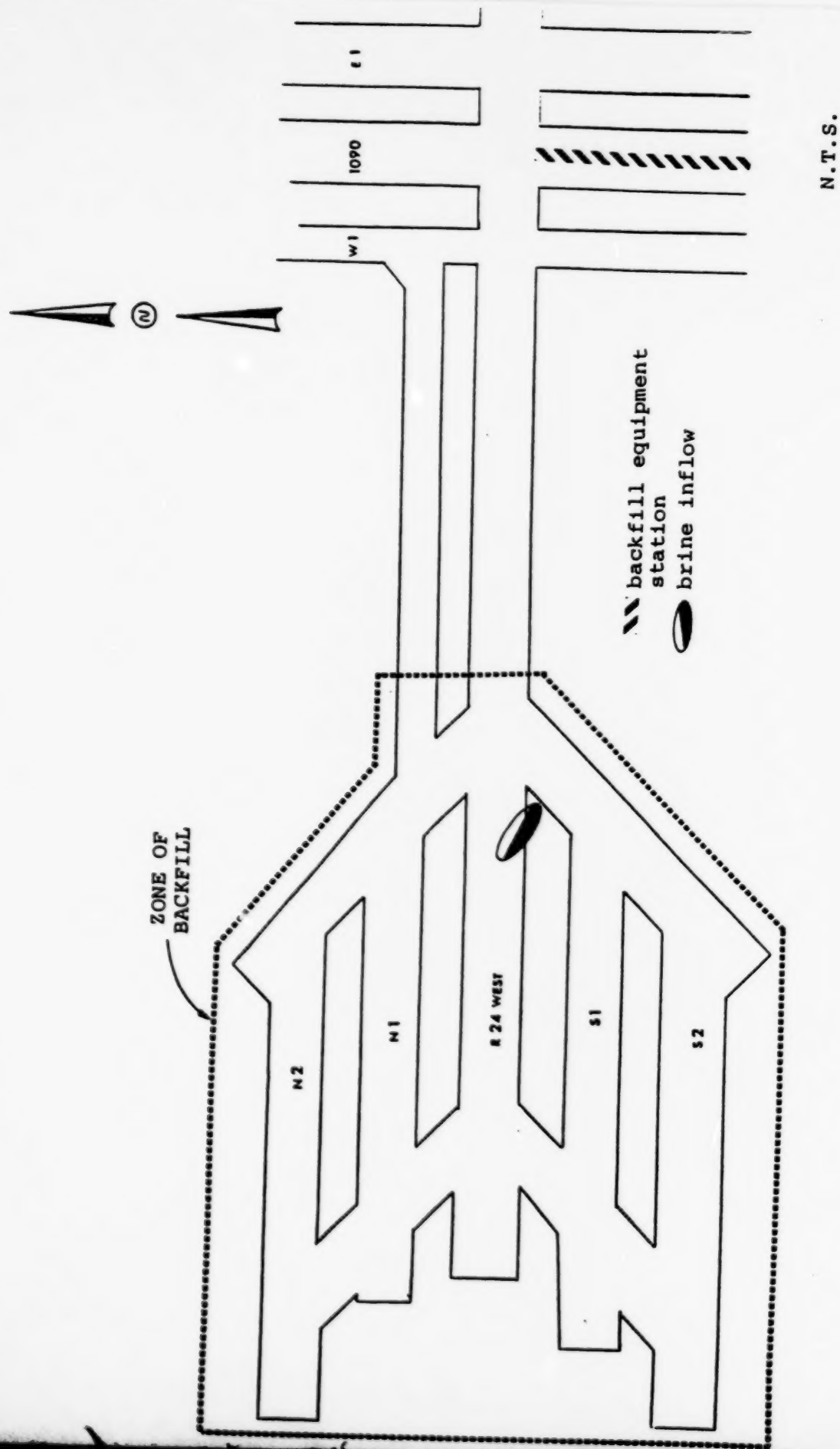


Figure 28. THE BACKFILLING PROGRAM FOR PANEL 109

8 CONCLUSIONS

This project involved laboratory and field research work. Diamond drilling, grouting and field instrumentation formed the core of the field work, which is summarized below.

1 - Access ways to the two panels used for the tests were rehabilitated and the two panels reopened. The rehabilitation work was performed using a Voest-Alpine Miner AM50 supported by scoop trams for haulage. A total of 2900 metres (9500 feet) of access to Panel 109 and 2200 metres (7200 feet) of access to Panel 209 were rehabilitated. Access into the panels was developed in preparation for the drilling, grouting, instrumentation and backfill programs. Approximately 670 metres (2200 feet) of access was developed in Panel 209, and approximately 457 metres (1500 feet) developed in Panel 109. Five diamond drilling stations were prepared in Panel 209 and four in Panel 109.

2 - An exploratory drilling program was established to investigate the geology and the source of brine entering Panels 209 and 109. A monitoring program of chemical composition, specific gravity, pH level, temperature, brine formation pressure and brine flow was initiated. The brine was found to be saturated with sodium chloride. The investigations have indicated that the most probable source of brine inflow in Block II

and in Block I is the Dawson Bay Formation. Brine flow studies show that the brine in Panel 109 and Panel 209 may come from the same source. The variation of brine flow with time was determined.

3 - A drilling and grouting program was prepared to control and ultimately seal the brine inflow in Panels 109 and 209, in preparation for the backfilling operation. Thirteen exploratory grout holes were drilled in Panel 209 and the overlying Dawson Bay Formation grouted to deflect brine inflow. The inflow in Panel 209, prior to grouting, was estimated at 82 lpm (18 lgpm). A primary cement grouting program reduced the total inflow from 82 lpm (18 lgpm) to approximately 27 lpm (6 lgpm). A secondary grouting program reduced the inflow from 27 lpm (6 lgpm) to approximately 9 lpm (2 lgpm). The grouting operation in Panel 209 resulted in a 89% reduction of the brine inflow volume. Four holes were initially drilled and tested in Panel 109 and flow and dye tests were performed. A drill hole layout consisting of six additional holes was designed and cement grout will be used to form a curtain of grout around the inflow.

4 - Selected sections in the panels were instrumented to evaluate the load/deformation characteristics of the surrounding strata. The first part of the instrumentation program in Panels 209 and 109 involves the gathering of information from previous studies undertaken in the area, including geophysical evaluations, geologic maps and exploration drill logs. A series of structural and stratigraphic cross sections have been

constructed to indicate the specific geology of the mine area in both panels. To monitor the stress changes and related closures in the backfill and surrounding strata a series of temporary and permanent instrumentation stations were developed in Panel 209. The temporary stations consisted of eleven room closure pin stations and two deep pin stations. These stations have established vertical and horizontal closure rates in Panel 209 averaging 0.76 cm/100 days (0.3 inches/100 days) and 1.24 cm/100 days (0.49 inches/100 days), respectively. Two full instrumentation stations, one pillar instrumentation station, four secondary instrumentation stations and two borehole instrumentation stations form the data gathering system established for Panel 209. The selected instruments for Panel 209 included two convergence meters for the rooms, four earth pressure cells and six piezometers for the backfill, five extensometers and three borehole pressure cells for the host salt and potash formations, and two stressmeters and four strain gauges for the Dawson Bay Formation.

Two room closure pin stations and one deep pin station were installed in Panel 109. These stations have established vertical and horizontal closure rates in Panel 109 averaging 0.86 cm/100 days (0.34 inches/100 days) and 1.14 cm/100 days (0.45 inches/100days), respectively. The selected instruments for Panel 109 included one convergence meter, two earth pressure cells, one piezometer, two borehole extensometers, two stressmeters and two strain gauges. One full instrumentation station,

one secondary instrumentation station and two borehole instrumentation stations form the data gathering system established for Panel 109.

5 - All the instruments installed in Panel 209 were connected to a data acquisition system, specially designed to receive and store the transmitted instrument data. The data acquisition system consists of a data logging system and an Otrona Attache host computer. Approximately 4600 metres (15100 feet) of cable was used for the connections between the instruments and the microprocessor, and a total of 84 wires were fed to the data acquisition system. All the instruments installed in Panel 109 will be connected to a manual reading station, specially designed to receive the transmitted instrument data. The manual reading station consists of a 12 channel switch box, an excitation unit, a voltmeter and a vibrating wire readout box. Approximately 1050 metres (3450 feet) of cable will be used for the connections between the instruments and the reading station, and a total of 30 wires will be fed to the data collection system.

6 - An invaluable data base is being collected to establish the long term behaviour of the rock formations typical of the Saskatchewan potash mines.

7 - The backfilling technique was selected: Pneumatic stowing. Salt muck for backfilling will be supplied by the AM50 and scoop trams will be used to feed the stowing system with the waste salt. Approx-

imately 20000 tonnes (22000 tons) of waste salt will be required to backfill Panel 209 and approximately 10000 tonnes (11000 tons) for Panel 109.

8 - An extensive program of laboratory tests was designed to investigate the basic physical characteristics of the mine rock formations and salt backfill. The Dawson Bay, First Red Bed and Second Red Bed Formations were core sampled and laboratory tested. Brazilian tests and uniaxial and triaxial compression tests were conducted. A total of 340 tests were performed at Queen's University. A summary of results is listed below:

- Dawson Bay:

Tensile strength	-	11 ± 2.8 MPa (1600 ± 400 psi)
Compressive strength	-	124 ± 25 MPa (18000 ± 3600 psi)
Young's Modulus	-	31026 ± 7580 MPa ($4.5 \pm 1.1 \times 10^6$ psi)
Poisson's Ratio	-	0.13 ± 0.04
Cohesion	-	20.7 MPa (3000 psi)
Angle of failure	-	71 ± 2.6 degrees
Friction angle	-	52 ± 5.2 degrees

- 1st Red Beds:

Tensile strength	-	7 ± 1.4 MPa (1016 ± 204 psi)
Compressive strength	-	64 ± 7 MPa (9300 ± 1080 psi)
Young's Modulus	-	17237 ± 1379 MPa ($2.5 \pm 0.2 \times 10^6$ psi)
Poisson's Ratio	-	0.08 ± 0.02
Angle of failure	-	75 ± 4 degrees
Friction angle	-	60 ± 8 degrees

- 2nd Red Beds:

Compressive strength	-	41.4 ± 6.7 MPa (6000 ± 968 psi)
Young's Modulus	-	17721 ± 2758 MPa ($1.7 \pm 0.4 \times 10^6$ psi)
Poisson's Ratio	-	0.17 ± 0.08
Angle of failure	-	62 ± 8 degrees
Friction angle	-	34 ± 15 degrees

The backfill material was sampled and a laboratory testing program initiated. The tests investigate some of the relevant variables involved with the backfilling operation: material composition, size analysis, density, porosity, permeability, moisture content, strength, etc.

APPENDIX A.

ROCK MECHANICS LABORATORY TESTS

DAWSON BAY, FIRST RED BEDS, SECOND RED BEDS

Prepared for:

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by:

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A.1 - INTRODUCTION

This report presents data on the physical properties of core from the Dawson Bay Formation and the 1st and 2nd Red Beds, collected at Central Canada Potash.

Three types of tests were performed: Uniaxial Compression Tests, Triaxial Compression Tests, Brazilian Tests (Tensile).

A total of 340 tests were performed as listed below:

# of Tests	Test Type
90	Uniaxial
14	Triaxial
236	Brazilian

The following boreholes were sampled: 84-2, 84-3 and 84-5 (Panel 109) , 84-9 and 85-9 (Panel 209).

The samples were selected to provide information on the variability of the Dawson Bay properties through its whole length. A limited number of tests was performed on the 1st and 2nd Red Beds.

The following properties were estimated, based on the tests: uniaxial compressive strength, triaxial compressive strength, tensile strength, Poisson's ratio, Young's modulus, failure angle, angle of internal friction, cohesion.

Test results are to be used in rock behaviour analysis for Panels 109 and 209 and in data reduction calculations for the installed instrumentation. The small laboratory sample testing may not represent the in situ properties as scale effects have not been explored.

A.2 - TEST PROCEDURES

A.2.1 - Specimen Preparation

- Specimens for Uniaxial and Triaxial Tests

The borehole core was 4.2 cm (1.655 inches) in diameter (BW) and well preserved. The core samples were cut by diamond sawing and the end faces finished on a lathe to ± 0.013 cm (± 0.005 inch) deviation from parallel. The core was cut to produce a specimen having a length to diameter ratio in the range of 2.2:1 to 2.5:1.

- Specimens for Brazilian Tests

The core samples were cut by diamond sawing and the end faces were finished on a surface grinder. Disks of thickness varying from 0.38 cm (0.15 inches) to 0.89 cm (0.35 inches) were produced.

A.2.2 - Uniaxial Compression Tests

The Uniaxial Compression Tests were used to estimate the Average Uniaxial Compressive Strength of the samples. Tests were performed in a Material Testing System (MTS) Model 810 servo-controlled compression loading frame. The tests were controlled under linearly-varying rates of specimen axial strain, set at approximately $10E-4$ strain/ second.

A.2.3 - Triaxial Compression Tests

The Triaxial Compression Tests were used to estimate the rock strength at different confining pressures and to develop Mohr-Coulomb failure locus parameters. Tests were performed in a Material Testing System (MTS) Model 810 servo-controlled compression loading frame. All tests were controlled under linearly-varying rates of specimen axial strain, set at approximately $10E-4$ strain/ second. Specimens were covered with a heavy rubber jacket to prevent contact of the oil (used for the confining medium) with the core. Confining pressures used ranged from 3.45 to 20.68 Mpa (500 to 3000 psi).

A.2.4 - Brazilian Tests

The Brazilian Tests were used to estimate the tensile strength of the Dawson Bay at depths where instrumentation is being installed. Tests were performed in a Material Testing System (MTS) Model 810 servo-controlled compression loading frame, which was conveniently adapted for tensile testing of disk samples.

A.3 - DISCUSSION OF RESULTS

The laboratory test results may not represent the in situ properties as scale effects have not been explored.

A.3.1 - Uniaxial and Triaxial Tests

The results of the Uniaxial and Triaxial tests are presented in Table 1.

The Dawson Bay samples have an average uniaxial compressive strength of 124 ± 25 MPa (18000 ± 3600 psi), an average Young's Modulus of 31026 ± 7580 MPa ($4.5 \pm 1.1 \times 10^6$ psi) and average Poisson's Ratio of 0.13 ± 0.04 .

The average results for the Dawson Bay, per hole tested are:

Hole #	Depth (feet)	Strength (psi)	Young's Modulus (x10E6 psi)	Poisson's Ratio	Angle of Failure (degrees)	Friction Angle (degrees)
84-2	52-72	21000	4.0	.09	73	56
	80-100	18100	5.1	.14	70	50
	106-128	17600	5.3	.15	69	48
	138-146	19500	4.8	.19	68	46
	154-174	7300	2.2	.15	71	52
	176-178	16600	4.9	.18	67	44
84-3		23200	4.2	.10	76	62
84-9		17400	6.0	.08	72	54
85-9		10800	3.6	.10	72	54

The triaxial test results (Dawson Bay) are listed below:

confining pressure (psi)	average strength (psi)
500	16000
1000	18500
1500	26000
2000	30000

The average angle of failure was estimated as 71 ± 2.6 degrees and the friction angle was estimated as 52 ± 5.2 degrees.

Based on the test results a Mohr-Coulomb Envelope was plotted (Figure 29) and the cohesion for the Dawson Bay Formation estimated as 20684 KPa (3000 psi).

The First Red Bed samples have an average uniaxial compressive strength of 64 ± 7 MPa (9300 ± 1080 psi), an average Young's Modulus of 17237 ± 1379 MPa ($2.5 \pm 0.2 \times 10^6$ psi) and average Poisson's Ratio of 0.08 ± 0.02 . The angle of failure and friction angle were estimated as 75 ± 4 degrees and 60 ± 8 degrees, respectively.

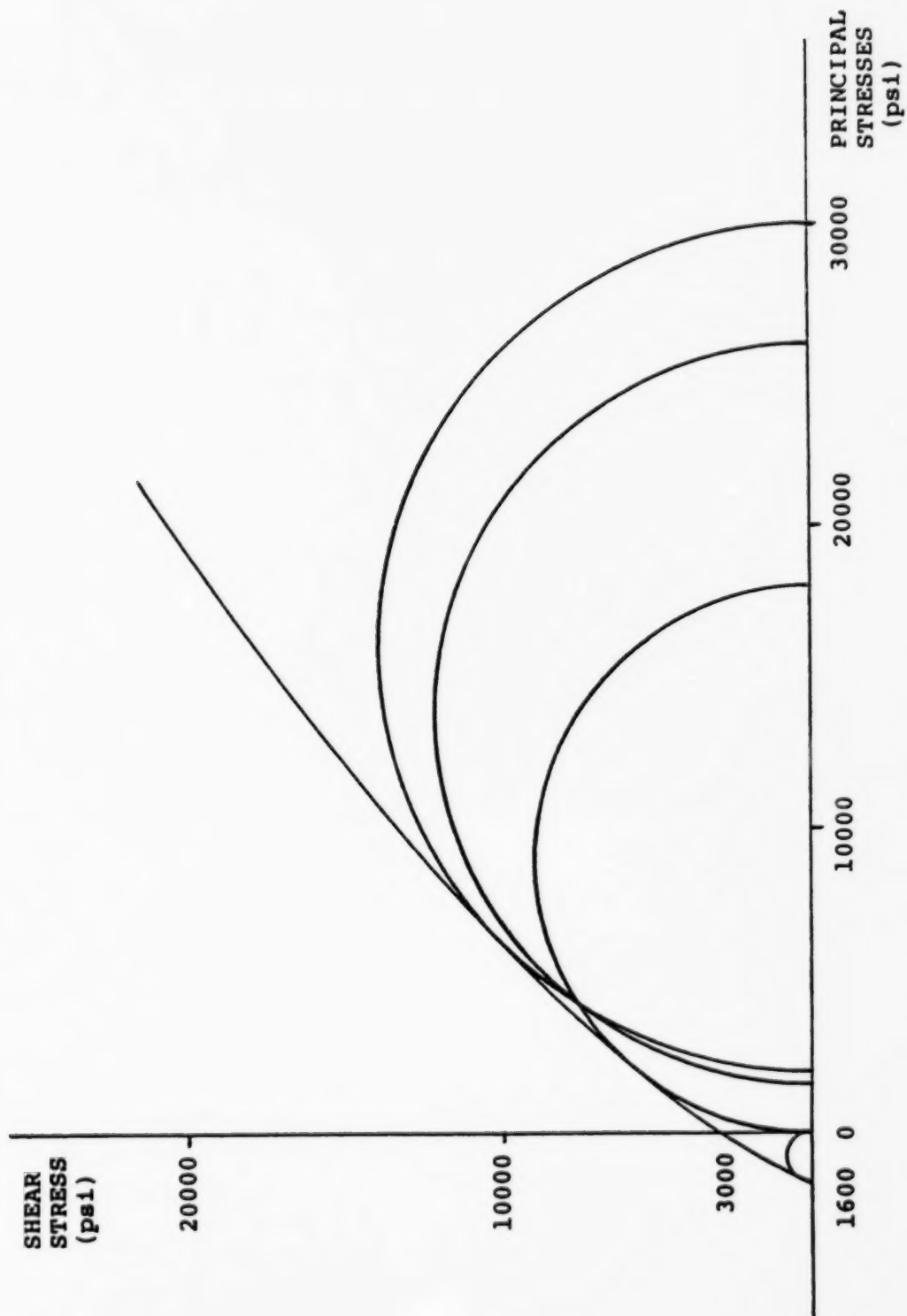


Figure 29. MOHR-COULOMB ENVELOPE - DAWSON BAY SAMPLES

The Second Red Bed samples have an average uniaxial compressive strength of 41.4 ± 6.7 MPa (6000 ± 968 psi), an average Young's Modulus of 11721 ± 2758 MPa ($1.7 \pm 0.4 \times 10^6$ psi) and average Poisson's Ratio of 0.17 ± 0.08 . The angle of failure and friction angle were estimated as 62 ± 8 degrees and 34 ± 15 degrees, respectively.

The average results for the Second Red Beds, per hole tested are:

Hole #	Strength (psi)	Young's Modulus ($\times 10^6$ psi)	Poisson's Ratio	Angle of Failure (degrees)	Friction Angle (degrees)
84-2	4900	1.353	.263	54	18
84-3	5400	2.330	.111	72	54
84-5	7000	1.440	.129	59	28
84-9	6500	1.543	.047	65	40

A.3.2 - BRAZILIAN TEST RESULTS

The results of the Brazilian tests are presented in Table 2.

The Dawson Bay samples have an average tensile strength of 11 ± 2.8 MPa (1600 ± 400 psi).

The average results per tested hole are shown in the following page.

The First Red Bed samples have an average tensile strength of 7.0 ± 1.4 MPa (1016 ± 204 psi).

Hole #	Depth (feet)	Tensile Strength (psi)
84-2	76-78	1474
	80-85	2012
	91-92	2039
	108	1829
	134-135	1609
	148-149	2036
	159-160	602
	170-171	1077
84-2 average		1585
84-3	80	1576
	92	1681
84-3 average		1629
84-9	96	1642
	112-120	1688
84-9 average		1665
85-9	118	985
	134	928
85-9 average		957

A.4 - CONCLUSIONS

Based on the test results, the following rock mechanics parameters were estimated:

- Dawson Bay:

Tensile strength	-	11 ± 2.8 MPa (1600 ± 400 psi)
Compressive strength	-	124 ± 25 MPa (18000 ± 3600 psi)
Young's Modulus	-	31026 ± 7580 MPa ($4.5 \pm 1.1 \times 10^6$ psi)
Poisson's Ratio	-	0.13 ± 0.04
Cohesion	-	20.7 MPa (3000 psi)
Angle of failure	-	71 ± 2.6 degrees
Friction angle	-	52 ± 5.2 degrees

- 1st Red Beds:

Tensile strength	-	7 ± 1.4 MPa (1016 ± 204 psi)
Compressive strength	-	64 ± 7 MPa (9300 ± 1080 psi)
Young's Modulus	-	17237 ± 1379 MPa ($2.5 \pm 0.2 \times 10^6$ psi)
Poisson's Ratio	-	0.08 ± 0.02
Angle of failure	-	75 ± 4 degrees
Friction angle	-	60 ± 8 degrees

- 2nd Red Beds:

Compressive strength	-	41.4 ± 6.7 MPa (6000 ± 968 psi)
Young's Modulus	-	17721 ± 2758 MPa ($1.7 \pm 0.4 \times 10^6$ psi)
Poisson's Ratio	-	0.17 ± 0.08
Angle of failure	-	62 ± 8 degrees
Friction angle	-	34 ± 15 degrees

The failure criteria for the formations were estimated, based on the well known rock elastic relations, and are summarized below:

- Dawson Bay

$$S1 = 18000 + 0.344 \times S3$$

$$Ts = 3000 + 1.280 \times S$$

$$Ts = 0.308 \times (S1 - S3)$$

$$S = .5 \times (S1 + S3) - 0.394 \times (S1 - S3)$$

- 1st Red Beds

$$S1 = 9300 + 0.268 \times S3$$

$$Ts = 1.732 \times S \quad (\text{assuming } C=0)$$

$$Ts = 0.250 \times (S1 - S3)$$

$$S = .5 \times (S1 + S3) - 0.433 \times (S1 - S3)$$

- 2nd Red Beds

$$S1 = 6000 + 0.532 \times S3$$

$$Ts = 0.675 \times S \quad (\text{assuming } C=0)$$

$$Ts = 0.415 \times (S1 - S3)$$

$$S = .5 \times (S1 + S3) - 0.280 \times (S1 - S3)$$

where,

S1 - major principal stress

S3 - minor principal stress

S - normal stress

Ts - shear stress

C - cohesion

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INST.	SPECIMEN LENGTH (IN)	L/D	ULTIMATE COMPRESS. STRENGTH (PSI)	ULTIMATE COMPRESS. STRENGTH (L/D=1/1) (PSI)	POISSON'S RATIO	YOUNG'S MODULUS (X10 ⁴ PSI)	CONFIN. PRESS. (PSI)	ANGLE OF FAIL. (DEG.)
1	84-2	2ND RED BEDS	40-41		4.002	2.418	4880	5610	.263	1.353	-	54
2	84-3	2ND RED BEDS	38		3.822	2.309	8367	9572	.111	2.330	-	72
3	84-5	2ND RED BEDS	49		3.794	2.292	6972	7970	.129	1.440	-	59
4	84-9	2ND RED BEDS	36		3.984	2.407	6508	7473	.047	1.543	-	65
5	84-2	1ST RED BEDS	199-204		3.622	2.189	9855	11205	.078	4.254	-	70
6	84-2	1ST RED BEDS	199-204		3.822	2.309	7438	8508	.077	2.369	-	75
7	84-2	1ST RED BEDS	199-204		3.611	2.189	9762	11100	.103	2.356	-	71
8	84-2	1ST RED BEDS	199-204		3.757	2.270	9994	11412	.056	2.973	-	79
9	84-2	1ST RED BEDS	199-204		3.800	2.296	8600	9832	.064	2.355	-	79
10	84-2	1ST RED BEDS	199-204		3.850	2.326	10227	11708	.095	2.427	-	79
11	84-2	DAWSON BAY	52-56		3.838	2.319	15805	18089	-	3.244	-	-
12	84-2	DAWSON BAY	52-56		3.840	2.320	26497	30327	.061	2.975	-	76
13	84-2	DAWSON BAY	60-62		3.835	2.317	18129	20747	.096	3.479	-	69
14	84-2	DAWSON BAY	60-62		3.818	2.307	19291	22067	.094	3.550	-	76
15	84-2	DAWSON BAY	60-62		3.838	2.319	19989	22877	.104	3.481	-	69
16	84-2	DAWSON BAY	60-62		3.811	2.303	15340	17540	-	2.444	1000	-
17	84-2	DAWSON BAY	60-62		3.812	2.303	13620	15577	.071	3.222	-	68
18	84-2	DAWSON BAY	64-65		3.873	2.340	16641	19063	.061	3.001	-	79
19	84-2	DAWSON BAY	64-66		3.770	2.278	17200	19646	.093	3.413	-	71
20	84-2	DAWSON BAY	66-68		3.722	2.249	10878	12407	.090	3.076	-	73
21	84-2	DAWSON BAY	66-68		3.756	2.269	22920	26160	-	3.576	1000	71

Table 1. UNIAXIAL AND TRIAXIAL TEST RESULTS

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INST. SPECIMEN LENGTH (IN)	L/D	ULTIMATE COMPRESS. STRENGTH (PSI)	ULTIMATE COMPRESS. STRENGTH (L/D=1/1) (PSI)	POISSON'S RATIO	YOUNG'S MODULUS (X10 ⁴ PSI)	CONFIN. PRESS. (PSI)	ANGLE FAIL. (DEG.)
22	84-2	DAWSON BAY	66-68	3.873	2.340	25427	29131	.096	4.445	-	73
23	84-2	DAWSON BAY	70-71	3.843	2.322	27659	31660	.091	5.104	-	74
24	84-2	DAWSON BAY	70-71	3.879	2.344	28820	33024	.099	6.011	-	75
25	84-2	DAWSON BAY	71-72	3.739	2.259	28356	32360	.122	6.045	-	75
26	84-2	DAWSON BAY	71-72	3.967	2.397	26032	29900	.109	5.901	-	68
27	84-2	DAWSON BAY	80-81	3.978	2.404	13759	15809	.183	5.917	-	75
28	84-2	DAWSON BAY	80-81	3.762	2.273	22313	25481	.192	5.596	-	78
29	84-2	DAWSON BAY	81-82	3.968	2.398	26960	30970	-	4.099	1500	62
30	84-2	DAWSON BAY	81-82	3.598	2.174	16270	18486	.127	4.614	-	74
31	84-2	DAWSON BAY	83.2	SG	3.861	13946	15971	.087	4.223	-	75
32	84-2	DAWSON BAY	84	3.902	2.358	15340	17589	.181	6.596	-	78
33	84-2	DAWSON BAY	87-88	3.795	2.293	21848	24974	.072	6.720	-	63
34	84-2	DAWSON BAY	98-99	3.728	2.253	23707	27047	.091	6.302	-	66
35	84-2	DAWSON BAY	99-100	3.749	2.265	30075	34330	-	3.983	1580	61
36	84-2	DAWSON BAY	99-100	3.906	2.360	13713	15725	-	5.001	-	58
37	84-2	DAWSON BAY	106-107	3.871	2.339	10831	12408	.058	3.428	-	76
38	84-2	DAWSON BAY	106-107	3.829	2.314	11854	13564	.079	2.967	-	71
39	84-2	DAWSON BAY	117-118	3.919	2.368	15665	17970	.189	6.625	-	73
40	84-2	DAWSON BAY	117-118	3.745	2.263	22313	25468	.153	6.963	-	-
41	84-2	DAWSON BAY	118-119	3.702	2.237	5113	5829	.052	2.015	-	79
42	84-2	DAWSON BAY	118-119	3.771	2.279	31600	36100	-	4.836	3000	60
43	84-2	DAWSON BAY	125-126	3.782	2.285	19523	22309	.150	7.032	-	71
44	84-2	DAWSON BAY	125-126	3.781	2.285	22778	26027	.153	6.334	-	77
45	84-2	DAWSON BAY	126-128	3.868	2.337	20918	23962	.207	4.828	-	74
46	84-2	DAWSON BAY	126-128	3.768	2.277	16409	18743	.257	4.463	-	60

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INST.	SPECIMEN LENGTH (IN)	L/D	ULTIMATE COMPRESS. STRENGTH (PSI)	ULTIMATE COMPRESS. STRENGTH (L/D=1/1) (PSI)	POISSON'S RATIO	YOUNG'S MODULUS (X10 ⁶ PSI)	CONFIN. PRESS. (PSI)	ANGLE FAIL. (DEG.)
47	84-2	DAWSON BAY	126-128		3.790	2.290	17897	20455	.122	5.220	-	60
48	84-2	DAWSON BAY	138-139		3.960	2.393	26497	30429	.190	5.260	-	-
49	84-2	DAWSON BAY	138-139		3.787	2.288	10691	12219	-	2.041	-	68
50	84-2	DAWSON BAY	140-142		3.932	2.376	19291	22137	.169	5.222	-	70
51	84-2	DAWSON BAY	140-142		3.769	2.277	24600	28100	-	3.688	500	67
52	84-2	DAWSON BAY	140-142		3.748	2.265	25799	29451	.227	5.808	-	68
53	84-2	DAWSON BAY	144-146		3.774	2.280	11249	12851	.100	4.010	-	-
54	84-2	DAWSON BAY	144-146		3.786	2.288	18129	20718	.173	5.028	-	68
55	84-2	DAWSON BAY	154-155		3.787	2.288	5113	5844	.112	1.514	-	68
56	84-2	DAWSON BAY	154-155		3.870	2.338	5578	6390	.122	2.027	-	-
57	84-2	DAWSON BAY	162		3.854	2.329	6508	7452	.170	1.861	-	78
58	84-2	DAWSON BAY	164-165		3.870	2.338	13481	15443	.235	3.598	-	-
59	84-2	DAWSON BAY	164-165		3.848	2.325	10459	11974	.197	3.045	-	72
60	84-2	DAWSON BAY	167	SG	3.745	2.263	8832	10081	.162	3.095	-	73
61	84-2	DAWSON BAY	168	ST	3.855	2.329	8600	9847	.168	2.990	-	-
62	84-2	DAWSON BAY	168.5		3.776	2.282	5811	6639	.128	2.006	-	-
63	84-2	DAWSON BAY	169-170		3.886	2.348	4649	5328	.155	1.680	-	69
64	84-2	DAWSON BAY	169-170		3.779	2.283	6600	7540	-	1.511	490	63
65	84-2	DAWSON BAY	170-171		3.839	2.320	6043	6917	.089	1.660	-	-
66	84-2	DAWSON BAY	174		3.782	2.285	5113	5843	.054	1.927	-	72
67	84-2	DAWSON BAY	176-178		3.569	2.156	14875	16885	.185	4.577	-	65
68	84-2	DAWSON BAY	176-178		3.853	2.328	15921	19374	.144	4.941	-	65
69	84-2	DAWSON BAY	176-178		3.795	2.293	17897	20458	.196	5.040	-	71
70	84-3	DAWSON BAY	87-88		3.732	2.255	23243	26519	.110	7.305	-	75

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INST.	SPECIMEN LENGTH (IN)	L/D	ULTIMATE COMPRESS. STRENGTH (PSI)	ULTIMATE COMPRESS. STRENGTH (L/D=1/1) (PSI)	POISSON'S RATIO	YOUNG'S MODULUS (X10 ⁴ *6 PSI)	CONFIN. PRESS. (PSI)	ANGLE FAIL. (DEG.)
71	84-3	DAWSON BAY	87-88		3.738	2.259	32070	36600	-	4.089	2000	79
72	84-3	DAWSON BAY	89	ST	3.871	2.339	8600	9852	-	3.428	-	-
73	84-3	DAWSON BAY	89	ST	3.833	2.316	16270	18618	-	3.168	-	80
74	84-3	DAWSON BAY	90		3.838	2.319	16735	19153	.010	4.919	-	-
75	84-3	DAWSON BAY	91		3.843	2.322	36260	41500	-	4.764	2000	67
76	84-3	DAWSON BAY	91		3.368	2.035	14875	16769	.056	4.639	-	-
77	84-9	DAWSON BAY	97.8	SG	3.807	2.300	25334	28969	.099	6.155	-	67
78	84-9	DAWSON BAY	97.8	SG	3.914	2.365	26032	29857	.075	7.278	-	77
79	84-9	DAWSON BAY	95.5		3.748	2.265	17571	20058	.096	5.575	-	75
80	84-9	DAWSON BAY	95.5		3.971	2.399	17432	20024	.085	6.153	-	77
81	84-9	DAWSON BAY	98-99		3.747	2.264	21848	24939	-	5.574	-	72
82	84-9	DAWSON BAY	98-99		3.927	2.373	13481	15467	.073	5.617	-	75
83	84-9	DAWSON BAY	112-120		3.871	2.339	14410	16508	.075	5.758	-	77
84	84-9	DAWSON BAY	112-120		3.807	2.300	17432	19933	.091	5.663	-	73
85	84-9	DAWSON BAY	112-120		3.793	2.292	17897	20457	.075	5.877	-	76
86	84-9	DAWSON BAY	114.8	SG	3.774	2.280	24404	27879	.080	6.683	-	72
87	84-9	DAWSON BAY	114.8	SG	3.819	2.308	18192	20738	.071	6.456	-	68
88	84-9	DAWSON BAY	116		3.791	2.291	11600	13260	-	-	500	74
89	84-9	DAWSON BAY	116		3.964	2.395	13945	16017	.083	5.897	-	69
90	84-9	DAWSON BAY	116		3.896	2.354	13016	14921	.077	5.366	-	71
91	84-9	DAWSON BAY	117		3.890	2.350	11350	13000	-	2.226	500	65
92	84-9	DAWSON BAY	118		3.881	2.345	16970	19440	-	2.887	1000	66
93	84-9	DAWSON BAY	118	ST	3.765	2.375	15340	17520	.113	6.088	-	67
94	84-9	DAWSON BAY	119		4.090	2.471	13016	14998	.091	6.337	-	76
95	85-9	DAWSON BAY	115.4	SG	3.778	2.283	22313	25493	.184	6.620	-	75

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INST.	SPECIMEN LENGTH (IN)	L/D	ULTIMATE COMPRESS. STRENGTH (PSI)	ULTIMATE COMPRESS. STRENGTH (L/D-1/1) (PSI)	POISSON'S RATIO	YOUNG'S MODULUS (X10 ⁴ PSI)	CONFIN. PRESS. (PSI)	ANGLE FAIL. (DEG.)
96	85-9	DAWSON BAY	116-118		3.521	2.127	7902	8956	.075	3.357	-	-
97	85-9	DAWSON BAY	116-118		3.803	2.298	18360	21000	-	2.720	1500	69
98	85-9	DAWSON BAY	116-118		3.772	2.279	7437	8496	-	2.805	-	75
99	85-9	DAWSON BAY	116-118		3.711	2.242	9064	10336	.113	3.286	-	64
100	85-9	DAWSON BAY	135		3.756	2.269	8135	9288	.098	2.851	-	75
101	85-9	DAWSON BAY	136		3.791	2.291	11156	12752	.068	4.699	-	75
102	85-9	DAWSON BAY	139		3.833	2.316	21380	24470	-	2.458	2000	72
103	85-9	DAWSON BAY	140-141	SG	3.733	2.256	9529	10873	.085	3.653	-	-
104	85-9	DAWSON BAY	140-141	ST	3.879	2.344	4880	5593	-	1.603	-	71

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
1	84-2	DAWSON BAY	76-78		.171	850	1912
2	84-2	DAWSON BAY	76-78		.209	790	1454
3	84-2	DAWSON BAY	76-78		.234	1000	1644
4	84-2	DAWSON BAY	76-78		.216	1050	1870
5	84-2	DAWSON BAY	76-78		.198	980	1904
6	84-2	DAWSON BAY	76-78		.206	600	1120
7	84-2	DAWSON BAY	76-78		.197	760	1484
8	84-2	DAWSON BAY	76-78		.253	1030	1566
9	84-2	DAWSON BAY	76-78		.217	650	1152
10	84-2	DAWSON BAY	76-78		.254	980	1484
11	84-2	DAWSON BAY	76-78		.236	800	1304
12	84-2	DAWSON BAY	76-78		.199	700	1353
13	84-2	DAWSON BAY	76-78		.229	730	1226
14	84-2	DAWSON BAY	76-78		.223	720	1242
15	84-2	DAWSON BAY	76-78		.173	630	1401
16	84-2	DAWSON BAY	80-85	SG	.145	730	1937
17	84-2	DAWSON BAY	80-85	SG	.194	1150	2280
18	84-2	DAWSON BAY	80-85	SG	.209	880	1620
19	84-2	DAWSON BAY	80-85	SG	.181	870	1843
20	84-2	DAWSON BAY	80-85	SG	.204	990	1857
21	84-2	DAWSON BAY	80-85	SG	.196	1150	2257

Table II. BRAZILIAN TEST RESULTS

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
22	84-2	DAWSON BAY	80-85	SG	.230	1200	2007
23	84-2	DAWSON BAY	80-85	SG	.211	1155	2106
24	84-2	DAWSON BAY	80-85	SG	.248	1230	1908
25	84-2	DAWSON BAY	80-85	SG	.204	2245	4233
26	84-2	DAWSON BAY	80-85	SG	.225	1385	2368
27	84-2	DAWSON BAY	80-85	SG	.152	890	2252
28	84-2	DAWSON BAY	80-85	SG	.158	540	1315
29	84-2	DAWSON BAY	80-85	SG	.191	720	1450
30	84-2	DAWSON BAY	80-85	SG	.121	920	2925
31	84-2	DAWSON BAY	80-85	SG	.199	1080	2088
32	84-2	DAWSON BAY	80-85	SG	.203	800	1516
33	84-2	DAWSON BAY	80-85	SG	.204	1110	2093
34	84-2	DAWSON BAY	80-85	SG	.238	1472	2379
35	84-2	DAWSON BAY	91-92	SG	.197	650	1269
36	84-2	DAWSON BAY	91-92		.192	1030	2064
37	84-2	DAWSON BAY	91-92		.198	900	1748
38	84-2	DAWSON BAY	91-92		.211	1070	1951
39	84-2	DAWSON BAY	91-92		.224	1260	2164
40	84-2	DAWSON BAY	91-92		.227	1350	2288
41	84-2	DAWSON BAY	91-92		.200	1260	2423
42	84-2	DAWSON BAY	91-92		.233	1320	2179
43	84-2	DAWSON BAY	91-92		.238	1510	2441
44	84-2	DAWSON BAY	91-92		.259	1570	2332
45	84-2	DAWSON BAY	91-92		.188	800	1637
46	84-2	DAWSON BAY	91-92		.221	1130	1367

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
47	84-2	DAWSON BAY	91-92		.239	1350	2173
48	84-2	DAWSON BAY	91-92		.230	1220	2040
49	84-2	DAWSON BAY	91-92		.169	1020	2121
50	84-2	DAWSON BAY	91-92		.175	1010	2220
51	84-2	DAWSON BAY	91-92		.182	900	1902
52	84-2	DAWSON BAY	91-92		.165	900	2098
53	84-2	DAWSON BAY	91-92		.237	1050	1704
54	84-2	DAWSON BAY	91-92		.199	1070	2068
55	84-2	DAWSON BAY	91-92		.176	910	1989
56	84-2	DAWSON BAY	91-92		.210	1090	1997
57	84-2	DAWSON BAY	91-92		.163	810	1912
58	84-2	DAWSON BAY	91-92		.159	850	2056
59	84-2	DAWSON BAY	108		.174	600	1326
60	84-2	DAWSON BAY	108		.221	960	1671
61	84-2	DAWSON BAY	108		.179	825	1773
62	84-2	DAWSON BAY	108		.199	1025	1981
63	84-2	DAWSON BAY	108		.180	785	1678
64	84-2	DAWSON BAY	108		.212	990	1796
65	84-2	DAWSON BAY	108		.219	1015	1783
66	84-2	DAWSON BAY	108		.167	700	1612
67	84-2	DAWSON BAY	108		.181	820	1743
68	84-2	DAWSON BAY	108		.201	865	1655
69	84-2	DAWSON BAY	108		.196	1130	2218
70	84-2	DAWSON BAY	108		.214	1140	2049
71	84-2	DAWSON BAY	108		.184	1000	2030
72	84-2	DAWSON BAY	108		.212	1120	2012

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
73	84-2	DAWSON BAY	108		.188	810	1657
74	84-2	DAWSON BAY	108		.252	1400	2137
75	84-2	DAWSON BAY	108		.216	1000	1781
76	84-2	DAWSON BAY	108		.202	615	1171
77	84-2	DAWSON BAY	108		.260	1590	2352
78	84-2	DAWSON BAY	108		.150	605	1551
79	84-2	DAWSON BAY	108		.210	1160	2125
80	84-2	DAWSON BAY	108		.232	1280	2122
81	84-2	DAWSON BAY	108		.191	865	1742
82	84-2	DAWSON BAY	108		.183	820	1724
83	84-2	DAWSON BAY	108		.157	800	1960
84	84-2	DAWSON BAY	134-135		.231	720	1199
85	84-2	DAWSON BAY	134-135		.234	995	1636
86	84-2	DAWSON BAY	134-135		.248	1240	1923
87	84-2	DAWSON BAY	134-135		.348	1685	1863
88	84-2	DAWSON BAY	134-135		.254	1060	1605
89	84-2	DAWSON BAY	134-135		.221	980	1706
90	84-2	DAWSON BAY	134-135		.249	1035	1599
91	84-2	DAWSON BAY	134-135		.271	915	1299
92	84-2	DAWSON BAY	134-135		.223	945	1630
93	84-2	DAWSON BAY	134-135		.208	840	1553
94	84-2	DAWSON BAY	134-135		.239	940	1513
95	84-2	DAWSON BAY	134-135		.211	750	1367
96	84-2	DAWSON BAY	134-135		.219	920	1616
97	84-2	DAWSON BAY	134-135		.206	740	1382

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
98	84-2	DAWSON BAY	134-135		.269	1045	1494
99	84-2	DAWSON BAY	134-135		.250	1240	1909
100	84-2	DAWSON BAY	134-135		.277	1345	1868
101	84-2	DAWSON BAY	134-135		.256	1200	1803
102	84-2	DAWSON BAY	148-149		.317	1805	3524
103	84-2	DAWSON BAY	148-149		.197	960	1875
104	84-2	DAWSON BAY	148-149		.266	3155	4562
105	84-2	DAWSON BAY	148-149		.236	1230	2005
106	84-2	DAWSON BAY	148-149		.266	1420	2053
107	84-2	DAWSON BAY	148-149		.274	1040	1460
108	84-2	DAWSON BAY	148-149		.229	1300	2184
109	84-2	DAWSON BAY	148-149		.226	925	1574
110	84-2	DAWSON BAY	148-149		.248	1040	1613
111	84-2	DAWSON BAY	159-160		.219	475	834
112	84-2	DAWSON BAY	159-160		.213	275	497
113	84-2	DAWSON BAY	159-160		.265	440	638
114	84-2	DAWSON BAY	159-160		.251	445	682
115	84-2	DAWSON BAY	159-160		.269	525	751
116	84-2	DAWSON BAY	159-160		.254	460	697
117	84-2	DAWSON BAY	159-160		.282	520	709
118	84-2	DAWSON BAY	159-160		.312	490	604
119	84-2	DAWSON BAY	159-160		.192	230	461
120	84-2	DAWSON BAY	159-160		.277	520	722
121	84-2	DAWSON BAY	159-160		.234	410	674
122	84-2	DAWSON BAY	159-160		.266	260	375
123	84-2	DAWSON BAY	159-160		.224	250	422

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
124	84-2	DAWSON BAY	159-160		.228	320	540
125	84-2	DAWSON BAY	159-160		.269	345	493
126	84-2	DAWSON BAY	159-160		.244	330	520
127	84-2	DAWSON BAY	170-171	SM-SG	.219	580	1019
128	84-2	DAWSON BAY	170-171	SM-SG	.276	750	1045
129	84-2	DAWSON BAY	170-171	SM-SG	.226	715	1217
130	84-2	DAWSON BAY	170-171	SM-SG	.203	510	966
131	84-2	DAWSON BAY	170-171	SM-SG	.218	495	873
132	84-2	DAWSON BAY	170-171	SM-SG	.231	640	1066
133	84-2	DAWSON BAY	170-171	SM-SG	.230	285	477
134	84-2	DAWSON BAY	170-171	SM-SG	.233	770	1271
135	84-2	DAWSON BAY	170-171	SM-SG	.221	625	1088
136	84-2	DAWSON BAY	170-171	SM-SG	.204	590	1113
137	84-2	DAWSON BAY	170-171	SM-SG	.191	760	1531
138	84-2	DAWSON BAY	170-171	SM-SG	.185	590	1227
139	84-2	DAWSON BAY	170-171	SM-SG	.203	225	426
140	84-2	DAWSON BAY	170-171	SM-SG	.228	632	1066
141	84-2	DAWSON BAY	170-171	SM-SG	.181	540	1148
142	84-2	DAWSON BAY	170-171	SM-SG	.279	920	1268
143	84-2	DAWSON BAY	170-171	SM-SG	.239	820	1320
144	84-2	DAWSON BAY	170-171	SM-SG	.247	765	1191
145	84-2	DAWSON BAY	170-171	SM-SG	.196	360	707
146	84-2	DAWSON BAY	170-171	SM-SG	.212	430	780
147	84-2	DAWSON BAY	170-171	SM-SG	.194	630	1249
148	84-2	DAWSON BAY	170-171	SM-SG	.207	800	1487

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
149	84-2	DAWSON BAY	170-171	SM-SG	.186	600	1241
150	84-2	1ST RED BEDS	199-204		.232	640	1061
151	84-2	1ST RED BEDS	199-204		.235	520	851
152	84-2	1ST RED BEDS	199-204		.275	900	1259
153	84-2	1ST RED BEDS	199-204		.312	950	1171
154	84-2	1ST RED BEDS	199-204		.197	650	1269
155	84-2	1ST RED BEDS	199-204		.233	390	644
156	84-2	1ST RED BEDS	199-204		.255	610	920
157	84-2	1ST RED BEDS	199-204		.241	580	926
158	84-2	1ST RED BEDS	199-204		.204	580	1094
159	84-2	1ST RED BEDS	199-204		.274	530	744
160	84-2	1ST RED BEDS	199-204		.262	840	1233
161	84-3	DAWSON BAY	80		.257	1040	1557
162	84-3	DAWSON BAY	80		.242	1470	2337
163	84-3	DAWSON BAY	80		.200	920	1769
164	84-3	DAWSON BAY	80		.218	630	1112
165	84-3	DAWSON BAY	80		.223	640	1104
166	84-3	DAWSON BAY	92	SM	.246	1132	1770
167	84-3	DAWSON BAY	92	SM	.200	1180	2270
168	84-3	DAWSON BAY	92	SM	.217	990	1755
169	84-3	DAWSON BAY	92	SM	.218	600	1059
170	84-3	DAWSON BAY	92	SM	.249	1240	1916
171	84-3	DAWSON BAY	92	SM	.222	1075	1863
172	84-3	DAWSON BAY	92	SM	.224	860	1477
173	84-3	DAWSON BAY	92	SM	.242	840	1335
174	84-3	DAWSON BAY	92	SM	.235	920	1504

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
175	84-3	DAWSON BAY	92	SM	.249	895	1383
176	84-3	DAWSON BAY	92	SM	.350	1260	1385
177	84-3	DAWSON BAY	92	SM	.258	1190	1774
178	84-3	DAWSON BAY	92	SM	.223	1040	1794
179	84-3	DAWSON BAY	92	SM	.249	1165	1800
180	84-3	DAWSON BAY	92	SM	.273	1235	1740
181	84-3	DAWSON BAY	92	SM	.208	970	1794
182	84-3	DAWSON BAY	92	SM	.224	1220	2095
183	84-3	DAWSON BAY	92	SM	.243	975	1543
184	84-9	DAWSON BAY	96	SG	.193	940	1873
185	84-9	DAWSON BAY	96	SG	.246	630	985
186	84-9	DAWSON BAY	96	SG	.198	1310	2545
187	84-9	DAWSON BAY	96	SG	.215	1090	1950
188	84-9	DAWSON BAY	96	SG	.199	680	1314
189	84-9	DAWSON BAY	96	SG	.248	830	1287
190	84-9	DAWSON BAY	96	SG	.241	650	1037
191	84-9	DAWSON BAY	96	SG	.309	1720	2141
192	84-9	DAWSON BAY	112-120	SG	.212	710	1288
193	84-9	DAWSON BAY	112-120	SG	.215	1000	1789
194	84-9	DAWSON BAY	112-120	SG	.178	890	1923
195	84-9	DAWSON BAY	112-120	SG	.210	1240	2271
196	84-9	DAWSON BAY	112-120	SG	.227	920	1552
197	84-9	DAWSON BAY	112-120	SG	.186	1090	2254
198	84-9	DAWSON BAY	112-120	SG	.177	900	1956
199	84-9	DAWSON BAY	112-120	SG	.166	820	1900

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
200	84-9	DAWSON BAY	119	SM	.185	820	1705
201	84-9	DAWSON BAY	119	SM	.179	510	1096
202	84-9	DAWSON BAY	119	SM	.173	550	1223
203	84-9	DAWSON BAY	119	SM	.210	950	1740
204	84-9	DAWSON BAY	119	SM	.216	720	1282
205	84-9	DAWSON BAY	119	SM	.202	910	1732
206	84-9	DAWSON BAY	119	SM	.210	830	1520
207	84-9	DAWSON BAY	119	SM	.179	820	1762
208	85-9	DAWSON BAY	118	SC	.183	460	967
209	85-9	DAWSON BAY	118	SC	.179	420	903
210	85-9	DAWSON BAY	118	SC	.203	590	1118
211	85-9	DAWSON BAY	118	SC	.201	490	938
212	85-9	DAWSON BAY	118	SC	.212	640	1161
213	85-9	DAWSON BAY	118	SC	.179	565	1214
214	85-9	DAWSON BAY	118	SC	.237	820	1331
215	85-9	DAWSON BAY	118	SC	.242	680	1081
216	85-9	DAWSON BAY	118	SC	.254	835	1265
217	85-9	DAWSON BAY	118	SC	.222	550	953
218	85-9	DAWSON BAY	118	SC	.232	375	622
219	85-9	DAWSON BAY	118	SC	.234	485	797
220	85-9	DAWSON BAY	118	SC	.156	270	666
221	85-9	DAWSON BAY	118	SC	.259	520	772
222	85-9	DAWSON BAY	134		.202	670	1276
223	85-9	DAWSON BAY	134		.181	470	933
224	85-9	DAWSON BAY	134		.181	440	915
225	85-9	DAWSON BAY	134		.222	690	1324

SPECIMEN #	BOREHOLE #	FORMATION	DEPTH (FEET)	INSTRUMENT	DISK THICKNESS (IN)	COMPRESSION LOAD (LBS)	TENSILE STRENGTH (PSI)
226	85-9	DAWSON BAY	134		.201	525	1005
227	85-9	DAWSON BAY	134		.214	600	1078
228	85-9	DAWSON BAY	134		.181	440	920
229	85-9	DAWSON BAY	134		.234	400	658
230	85-9	DAWSON BAY	134		.239	420	676
231	85-9	DAWSON BAY	134		.237	395	641
232	85-9	DAWSON BAY	134		.221	485	844
233	85-9	DAWSON BAY	134		.232	545	904
234	85-9	DAWSON BAY	134		.229	535	899
235	85-9	DAWSON BAY	134		.183	460	967
236	85-9	DAWSON BAY	134		.267	645	929

APPENDIX B.

PROPOSAL FOR LABORATORY TESTING OF WASTE SALT BACKFILL

submitted to:

Central Canada Potash

Colonsay - Saskatchewan

by:

Euler DeSouza

B.1 - INTRODUCTION

It is proposed that a series of laboratory tests be conducted to determine the mechanical behavior of waste salt when simulated as a backfill material.

Some of the relevant variables to be considered include: mineral composition, screen analysis, specimen size, density, porosity, permeability, moisture content, temperature, setting time, confining stress, loading rate.

Some of the properties and relations to be evaluated include: load-bulk density relations; rate of compression per load increment; stress-strain relation; angle of friction and cohesion; porosity, void ratio, water content, strength and deformation properties at different densities.

A proposal for testing procedure is described below, and summarized in the chart shown in Figure 30.

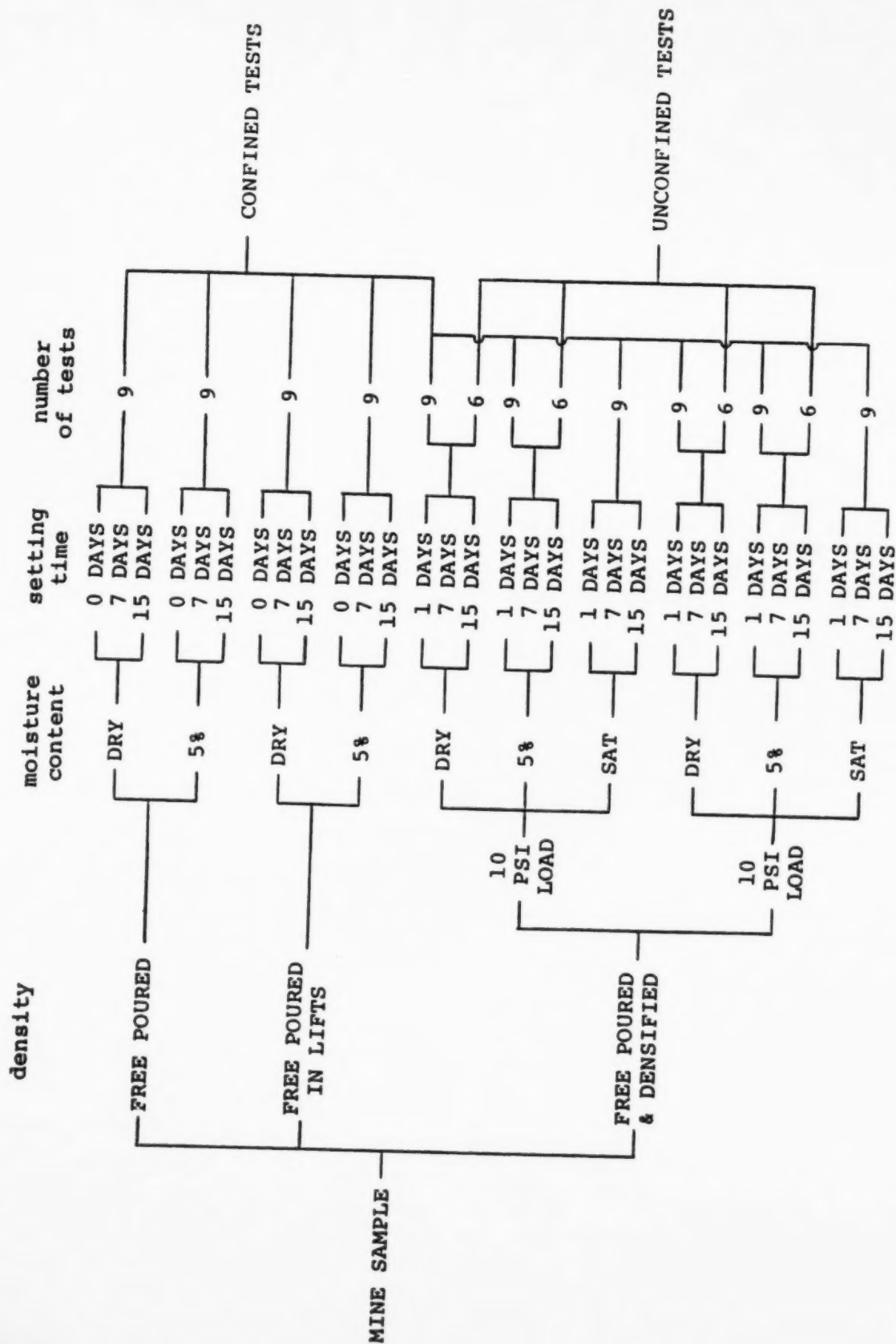


Figure 30. LABORATORY TESTING FLOW CHART

B.2 - TESTING PROCEDURE

- Granulometry: the material will be crushed and then screened to produce a uniform sample of 0.635 cm (-1/4") in size, to match with the proposed field application.:
- Specimen size: the specimens will have a cylindrical shape with size 10 cm DIA x 20 cm (4"DIA x 8") (height to width ratio of 2:1), in order to eliminate grain size effects. The specimens will be prepared in PVC molds.
- Moisture content: the material will be tested under different moisture contents to determine moisture/density effects on backfill strength. The material will be tested "dry" (as received), at 5% moisture, and saturated (brine outbreak in backfilled area).
- Specimen preparation: tests will be performed at different densities in order to define the degree of densification at which the backfill will acquire maximum strength. Three test densities are proposed:

- free poured - specimens are prepared by simply pouring the material into the moulds from a fixed height (0.91 m (3 feet) from mould top) and at a constant feed rate.

- free poured in lifts - free poured type specimens are first prepared as described above; then they will be placed in a shaking table (with fixed frequency and amplitude) for 30 seconds. The lowest possible frequency and highest possible amplitude ranges will be used to avoid the production of fines.

- free poured and densified - free poured type specimens are first prepared as previously described, and then densified using standard quasi-static consolidation methods. Axial preload stresses of 68.9 KPa (10 psi) and 689 KPa (100 psi) will be used. Consolidation curves (vertical deformation versus time) will be produced. Specimens with 1, 7 and 15 day setting times will be tested.

- Tests: the "free poured" and "free poured in lifts" specimens will be tested confined (the unconsolidated material will not produce unconfined strength); the "free poured and densified" specimens will be tested unconfined and confined.

"unconfined tests" - specimens with 7 and 15 day setting times will be used for the unconfined tests. Those tests are standard unconfined

creep consolidation tests, and the maximum applied axial load will be in the order of 50-60% the unconfined strength of the material.

"confined tests" - the unconsolidated and consolidated (with 1, 7 and 15 day setting times) specimens will be tested confined. Those tests are triaxial creep simulation tests, and will be performed under constant confining stresses. The applied axial load is maintained constant and when secondary creep is achieved an instantaneous increment in axial load is applied (increments in the order of 10-50 psi will be used); the procedure repeated until specimen failure (tertiary creep).

B.3 - ESTIMATION OF MINE SAMPLE SIZE

Estimated number of tests (Figure 25): 114

Specimen volume: 1655 cu.cm (101 cu.in.)

Total sample volume: 188,680 cu.cm (11,514 cu.in. or 6.66 cu.ft.)

Loose density of material: 1393.6 Kg/cu.m (87 lbs/cu.ft.)

Total sample weight: 263 Kg (580 lbs)

Considering losses during grinding, sampling, handling,
and the possible need of more tests:

RECOMMENDED SAMPLE VOLUME: two 204.6 l (45 l. gallon) containers
(correspondent weight: 567 Kg (1250 lbs))

APPENDIX C.

TECHNICAL SPECIFICATIONS FOR THE INSTRUMENTATION PROGRAM

prepared for:

Central Canada Potash

Colonsay - Saskatchewan

by:

Euler DeSouza

C.1 - STRESSMETER

Model - Geokon 4300EX

Type - Vibrating Wire

Range - 70 MPa

Sensitivity - 2%

Temperature Range - -29 to 65 degrees

Material - Stainless Steel

Gauge Wire - 1086 Music wire

Cable - 2 conductor shielded, 22 gage

Excitation Voltage - 5 voltage square wave

Frequency Range - 450-6000 Hz

C.2 - STRAIN GAUGE

Model	- Irad EM-5
Type	- Vibrating Wire
Range	- 3000 microstrain
Sensitivity	- 1 microstrain
Temperature Range	- -40 to 66 degrees
Material	- Stainless Steel
Gauge Wire	- Music wire
Cable	- 4 conductor, shielded
Excitation Voltage	- 5 volts
Frequency Range	- 400-880 Hz

C.3 - EARTH PRESSURE CELL

Model	- Geokon 4800E
Type	- Vibrating Wire
Range	- 34.5 psi
Sensitivity	- 0.1% F.S.
Temperature Range	- -29 to 65 degrees
Material	- Stainless Steel
Gauge Wire	- Music wire
Cable	- 2 conductor shielded
Excitation Voltage	- 5 volt square wave
Frequency Range	- 1200-2000 Hz

C.4 - PIEZOMETER

Model	- Geokon 4500S
Type	- Vibrating Wire
Range	- 5000 psi
Sensitivity	- 0.5% F.S.
Temperature Range	- -20 to 150 degrees
Material	- Stainless Steel
Gauge Wire	- Music wire
Cable	- 4 conductor direct burial, 22 gage
Excitation Voltage	- 5 volt square wave
Frequency Range	- 2000-3000 Hz

C.5 - BOREHOLE PRESSURE CELL

Model - Colma Dur

Transducer - Schaevitz model P2551

Range - 5000 psi

Excitation Voltage - 11 tp 18 VDC

Full Range Output - 2.5 VDC

Cable - 4 conductor direct burial, 22 gage

C.6 - HORIZONTAL EXTENSOMETER

Model - Three Anchor Point Extensometer

Transducer - Penny & Giles HLP90/SAI/150/GK4-09

Range - 150 mm

Excitation Voltage - 11 tp 18 VDC

Full Range Output - 2.5 VDC

Cable - 8 conductor direct burial, 22 gage

C.7 - BACK EXTENSOMETER

Model - Two Anchor Point Extensometer

Transducer - Penny & Giles HLP90/SAI/150/GK4-09

Range - 165 mm

Excitation Voltage - 11 tp 18 VDC

Full Range Output - 2.5 VDC

C.8 - FLOOR EXTENSOMETER

Model - Two Anchor Point Extensometer

Transducer - Penny & Giles HLP90/SAI/150/GK4-09

Range - 150 mm

Excitation Voltage - 11 tp 18 VDC

Full Range Output - 2.5 VDC

C.9 - CONVERGENCE METER

Model - Standard

Transducer - Penny & Giles

Range - 900 mm

Excitation Voltage - 11 tp 18 VDC

Full Range Output - 2.5 VDC

C.10 - VIBRATING WIRE READOUT UNIT

Model - Geokon GK-401

Range - 450 to 6000 Hz

Sensitivity - .001%

Temperature Range - -30 to 50 degrees

Excitation - 5 voltage square wave

Display - 5-digit LCD

Microprocessor - 3 MHZ CPU

C.11 - INSTRUMENT WIRE

Type - Direct Burial, shielded

Gauge size - 22 gauge, in 2, 3 and 6 pair wire

APPENDIX D.

INSTRUMENTATION IDENTIFICATION AND WIRING DIAGRAMS FOR
PANEL 209

prepared for:

Central Canada Potash

Colonsay - Saskatchewan

by:

Euler DeSouza

LIST OF SYMBOLS

BPC - Borehole Pressure Cell

HEX - Horizontal Extensometer

REX - Roof Extensometer

FEX - Floor Extensometer

CM - Convergence Meter

EPC - Earth Pressure Cell

PZ - Piezometer

STR - Stress Meter

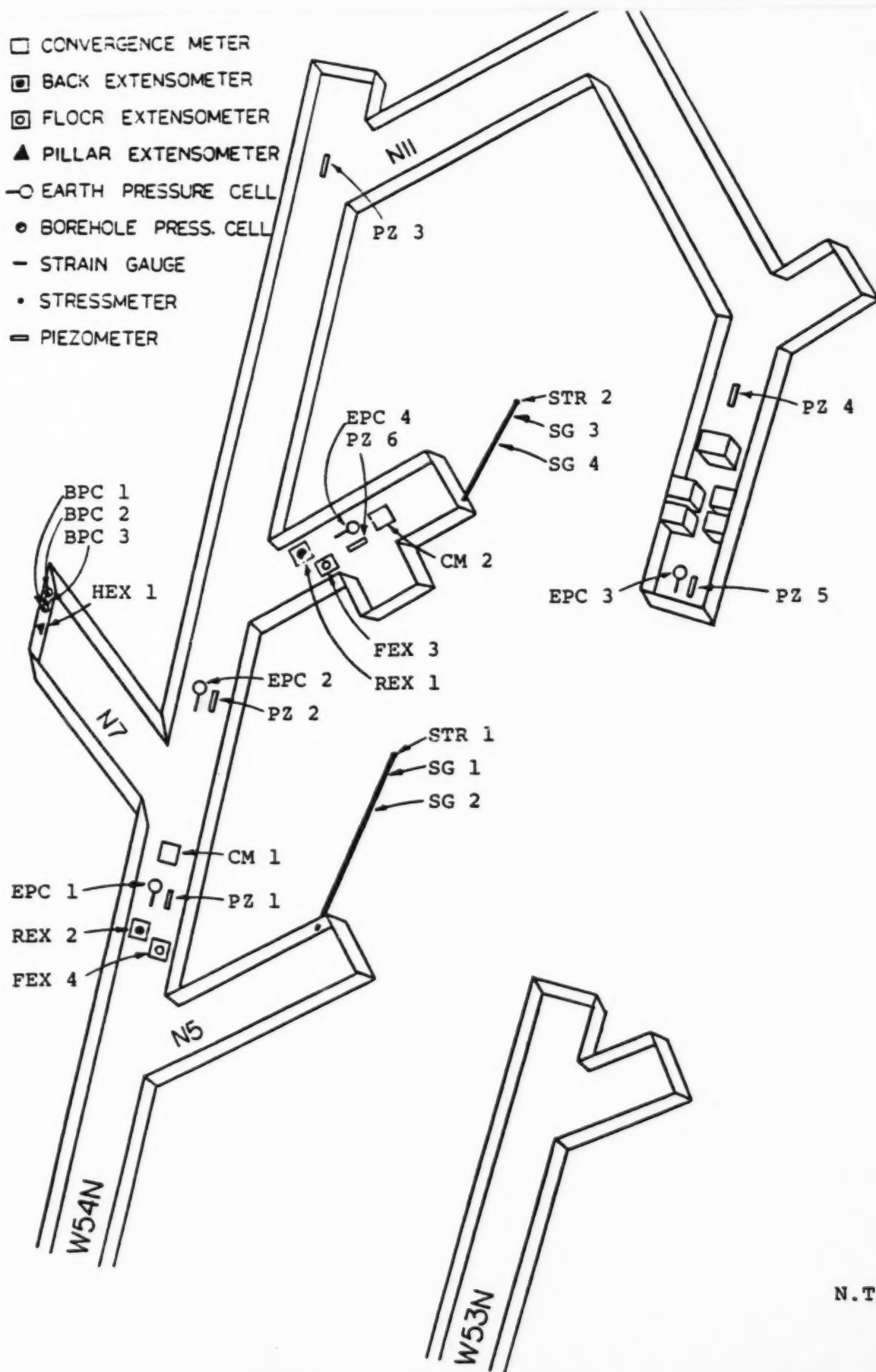
SG - Strain Gauge

E - Excitation Voltage

S - Output Signal

A, B, C - Potentiometer Designation

- CONVERGENCE METER
- ▣ BACK EXTENSOMETER
- ▢ FLOOR EXTENSOMETER
- ▲ PILLAR EXTENSOMETER
- EARTH PRESSURE CELL
- BOREHOLE PRESS. CELL
- STRAIN GAUGE
- STRESSMETER
- PIEZOMETER



N.T.S.

Figure 31. INSTRUMENTATION IDENTIFICATION - PANEL 209

	LATITUDE (N)	DEPARTURE (E)
BPC 1	147172	135914
BPC 2	147175	135910
BPC 3	147174	135912
HEX 1	147170	135916
EPC 1	147049	136017
EPC 2	147098	136017
EPC 3	147220	136210
EPC 4	147183	136044
PZ 1	147049	136017
PZ 2	147098	136017
PZ 3	147360	136016
PZ 4	147296	136201
PZ 5	147220	136210
PZ 6	147183	136044
FEX 3	147182	136043
FEX 4	147047	136016
REX 1	147182	136043
REX 2	147047	136018
CM 1	147055	136018
CM 2	147184	136046
Hole 84-9	Collar: 147018N, 136095E	
	Dip: 43° Azimuth: 4°	
STR 1	Depth: 118'	
SG 1	Depth: 114.9'	
SG 2	Depth: 97.8'	
Hole 85-2	Collar: 147246N, 136104E	
	Dip: 43° Azimuth: 16°	
STR 2	Depth: 142'	
SG 3	Depth: 133'	
SG 4	Depth: 115.4'	

Figure 32. INSTRUMENTATION LOCATION - PANEL 209

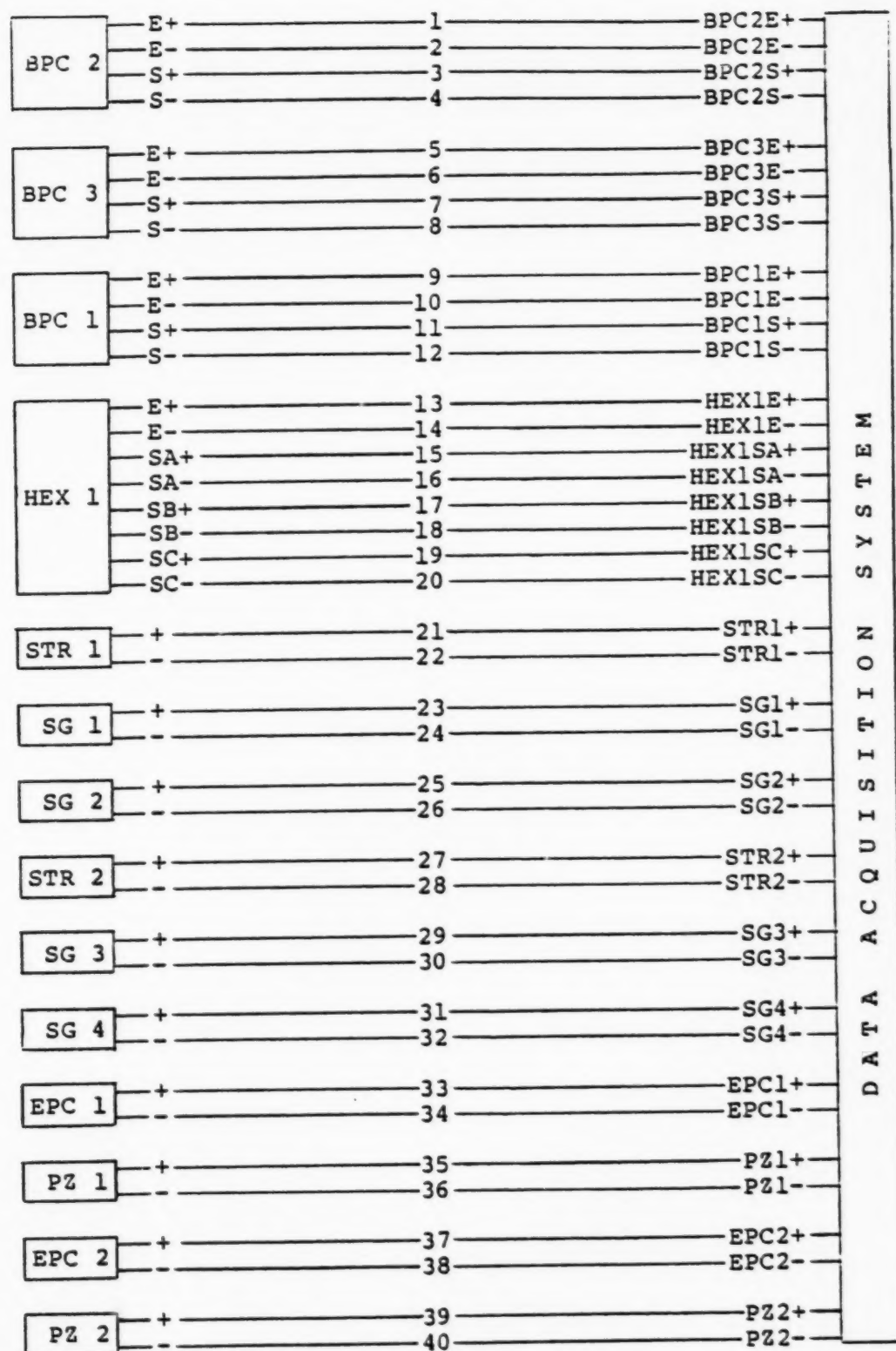


Figure 33. GENERAL WIRING DIAGRAM - PANEL 209

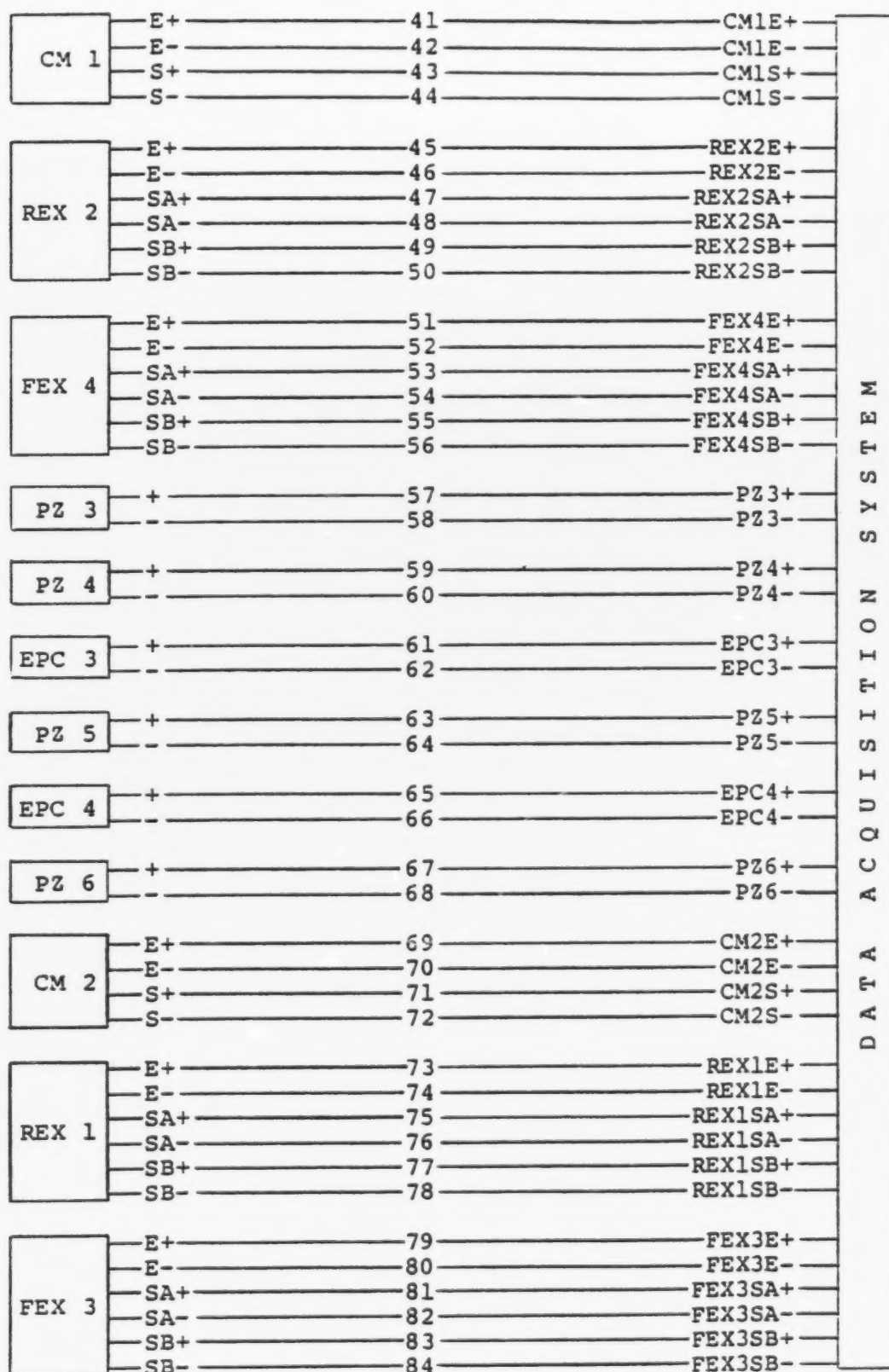


Figure 33. GENERAL WIRING DIAGRAM - PANEL 209 (continued)

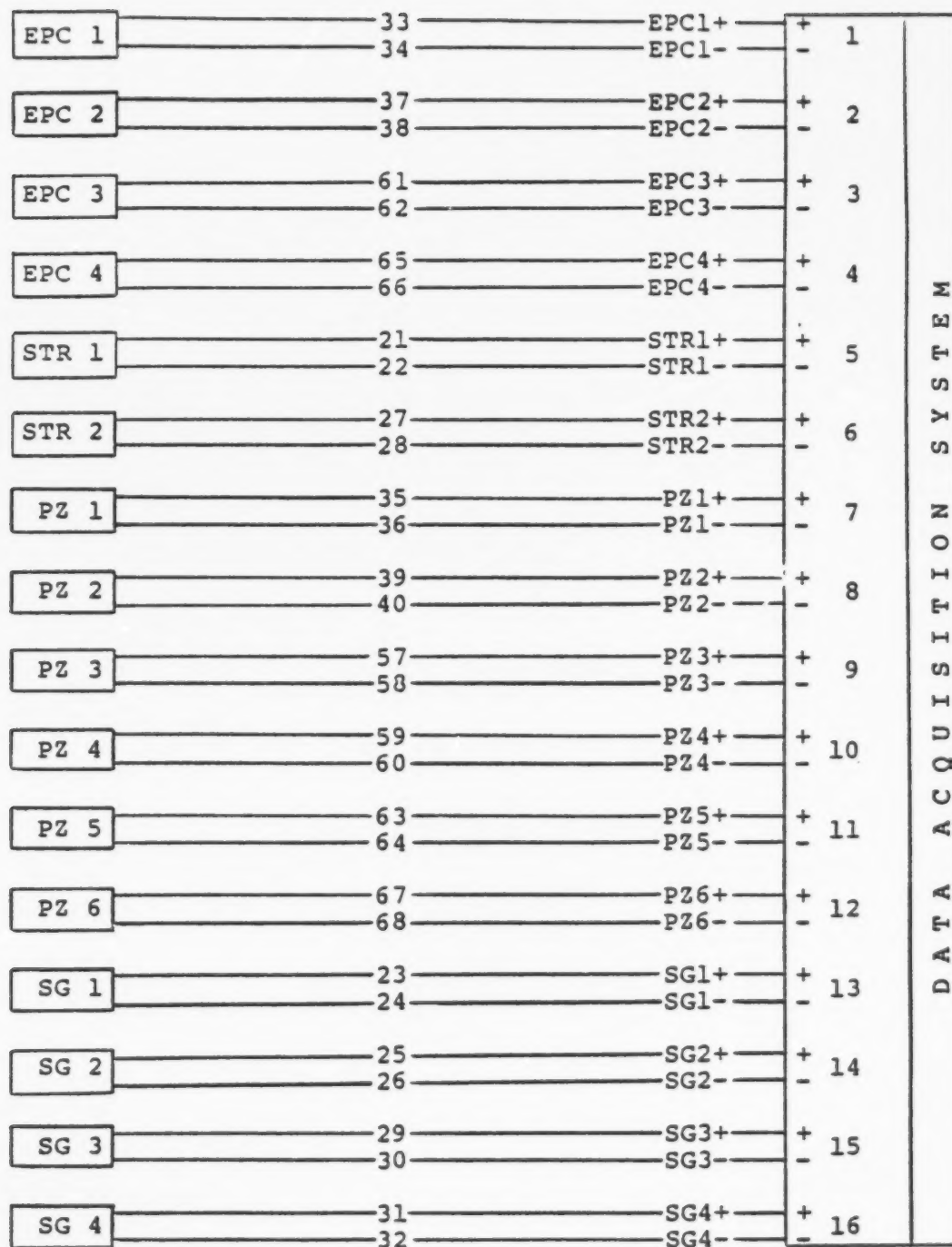


Figure 34. VIBRATING WIRE CONNECTIONS TO DATALOGGER

APPENDIX E.

INSTRUMENTATION IDENTIFICATION AND WIRING DIAGRAMS FOR
PANEL 109

prepared for:

Central Canada Potash

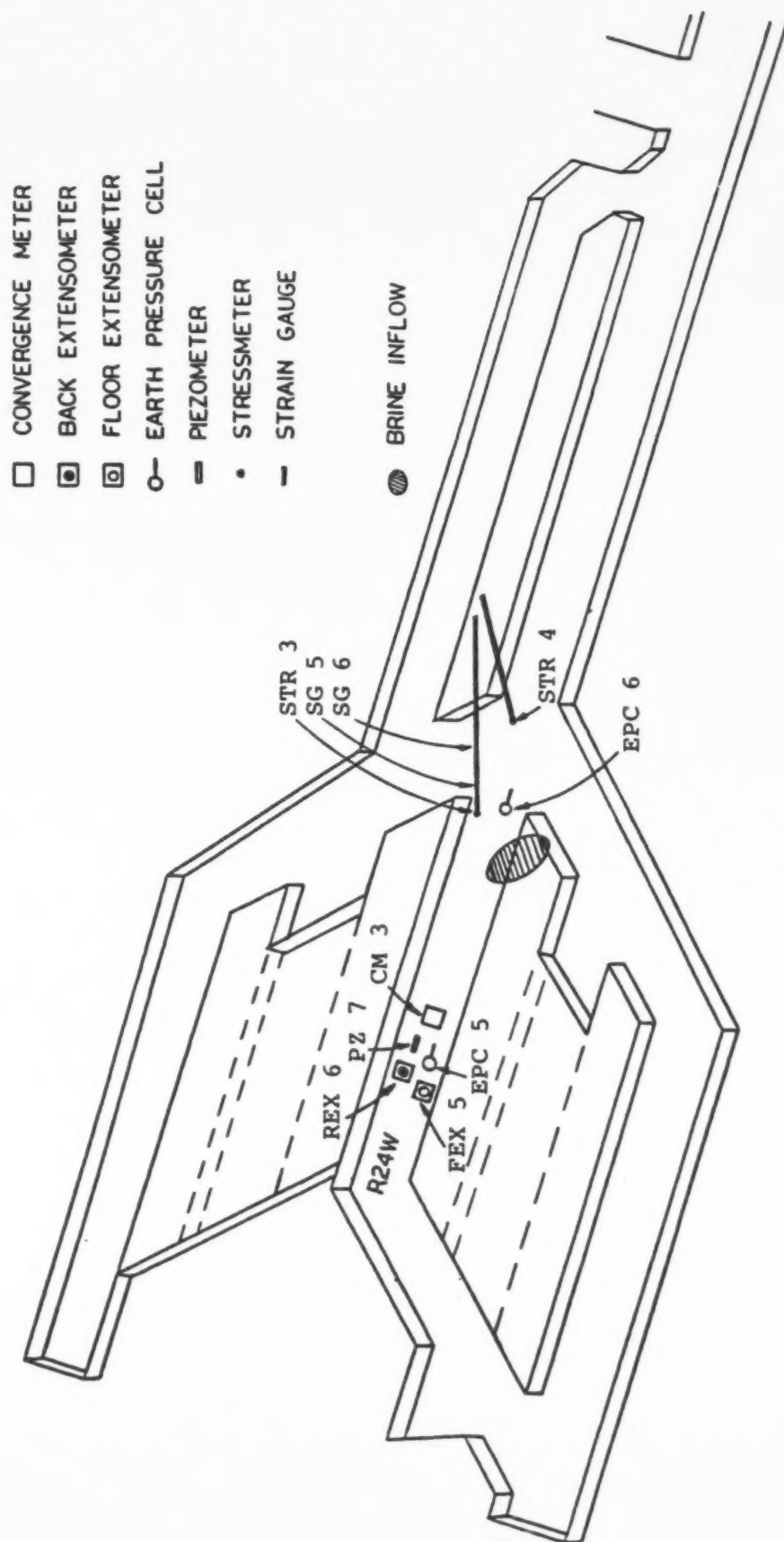
Colonsay - Saskatchewan

by:

Euler DeSouza

LIST OF SYMBOLS

BPC	- Borehole Pressure Cell
REX	- Roof Extensometer
FEX	- Floor Extensometer
CM	- Convergence Meter
EPC	- Earth Pressure Cell
PZ	- Piezometer
STR	- Stress Meter
SG	- Strain Gauge
E	- Excitation Voltage
S	- Output Signal
A, B	- Potentiometer Designation



N.T.S.

Figure 36. INSTRUMENTATION IDENTIFICATION - PANEL 109

	LATITUDE (N)	DEPARTURE (E)
EPC 5	142550	135752
EPC 6	142550	135880
PZ 7	142550	135752
REX 6	142550	135750
FEX 5	142550	135750
CM 3	142550	135755
Hole 84-2	Collar: 142591N, 135927E Dip: 53° Azimuth: 252°	
STR 3	Depth: 168'	
SG 5	Depth: 167'	
SG 6	Depth: 83.2'	
Hole 84-3	Collar: 142592N, 135931E Dip: 55° Azimuth: 241°	
STR 4	Depth: 89'	

Figure 37. INSTRUMENTATION LOCATION - PANEL 109

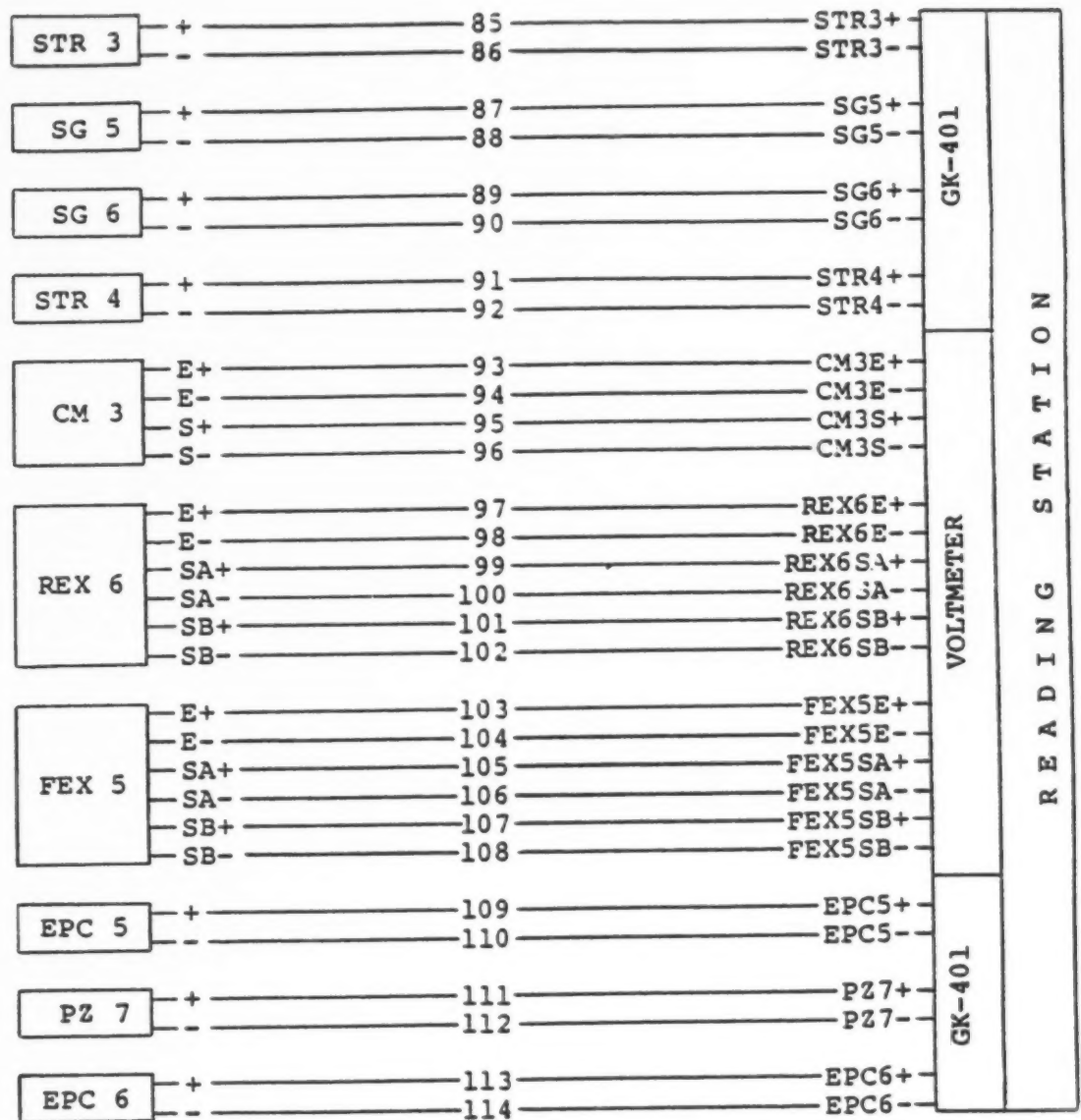


Figure 38. GENERAL WIRING DIAGRAM

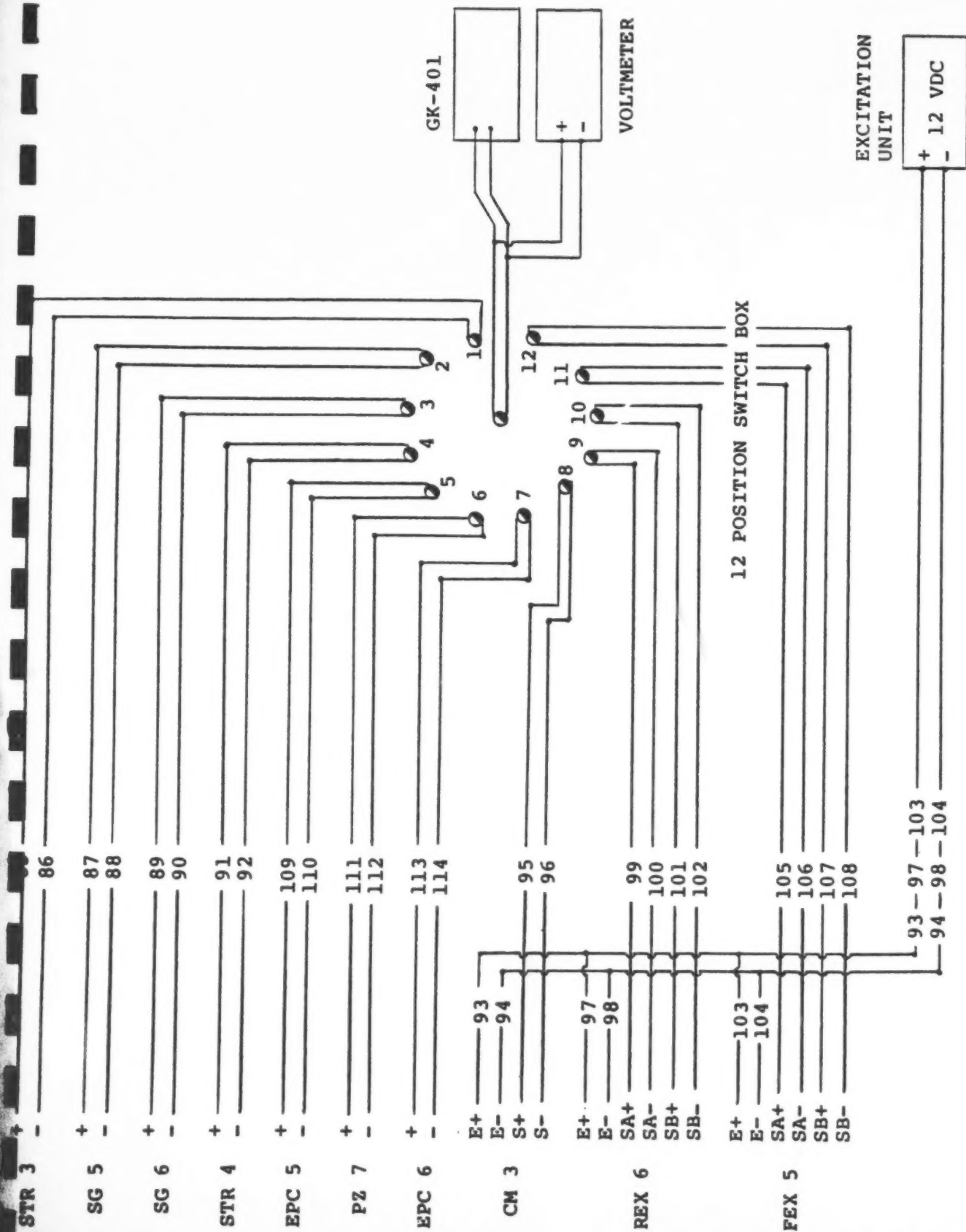


Figure 39. VIBRATING WIRE CONNECTIONS TO READING STATION